MODIFICATION OF FLOWERING, SEX EXPRESSION AND FRUITING OF SELECTED CUCURBITS BY GROWTH-REGULATING CHEMICALS

By

MOHAMED ABDEL-RAHMAN

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DEDICATION

To my parents, wife, daughter, and friends this dissertation is humbly dedicated with affection.

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Abstract of Dissertation Presented to the Graduate Council
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By

Mohamed Abdel-Rahman

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Chairman: Dr. B. D. Thompson
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An experimental program was designed to study the use of growth regulating chemicals for modification of flowering, sex expression, and fruiting of cucurbitaceous crops. The objectives were, first: to increase earliness, to increase total yield, and/or to induce concentration of flowering and fruit-set into a shorter period; second: to determine the mechanism by which these regulators produce their effect.

Crops used in these studies were cucumber--Cucumis sativus, 'Ashley,' cantaloupe--Cucumis melo, 'Florida #1,' summer squash--Cucurbita pepo, 'Yellow Straightneck' and 'Zucchini,' and watermelon--Citrullus vulgaris, 'Charlston Gray.' Chemicals selected were maleic hydrazide, triiodobenzoic acid, naphthaleneacetic acid, indoleacetic acid, and gibberellic acid. Applications were by spraying the foliage or by soaking the seeds in chemical solutions.

Treatments with MH, NAA, TIBA, and IAA inhibited vegetative growth, suppressed staminate and enhanced pistillate flower formation. Treatments with GA induced vegetative growth, enhanced

staminate and suppressed pistillate flower formation.

Early and total yields were increased by spraying the plant with 100 ppm of MH, NAA, or IAA at the four-leaf stage, in all of the four crops. However, concentration of yield in a shorter harvesting period resulted from treatments with TIBA at 50 or 100 ppm and NA at 150 or 200 ppm.

Experimental results, observations, and a review of pertinent literature appear to support the following hypothesis: Floral primordium in monoecious crops passes through a bisexual stage after which it expresses itself into one sex form or another according to the physiological and environmental conditions. The ratio of endogenous levels of auxins to gibberellin plays an important role in sex expression. The higher the ratio the more the tendency to female sex expression and the lower the ratio the more maleness the tendency. This role might be as a direct result from the effect of these hormones on gene expression and repression, or an indirect result of their effect on plant growth and metabolism.

On the same basis, NAA might modify sex expression by increasing auxin levels in the tissues or by diluting the effect of GA. However, MH and TIBA may be exerting their effect through a direct interaction with IAA and GA to modify their ratio, inhibition of polar transport of auxin through the stem, thus increasing the level of IAA around floral primordia, or inhibition of plant growth which might result in an accumulation of auxin and increase their level in the stem and around the floral primordia.

CHAPTER I

INTRODUCTION

Sex expression in flowering plants has drawn the attention of many research workers during the last century. Although most of the early work reflected genetic interest, the majority of recent research workers have been concerned with the physiology of this process.

Some of the most important aspects of the biology of the Cucurbitaceae are the integral elements of the flowering process. Sex expressions, flower formation, fruit set, and fruit growth and development are necessary steps leading to good crop production. Many factors which control the flowering process must be in the proper combination to produce desirable flowering and fruiting characteristics to achieve this end. These characteristics would involve not only sexual differentiation but the time of appearance and proportion of pistillate or hermaphroditic flowers on which fruit production depends.

Factors interacting to control sex expression in plants are genetic, environmental, and chemical. Much research has been conducted on the use of growth-regulating chemicals for modification of sex expression. However, little effort has been directed toward the practical application of research findings.

In planning the program for this study, two questions were posed. First, are any of the reported growth-regulating chemicals of practical use in the production of cucurbits in Florida? Second, what is the mechanism by which these chemicals produce their effects?

A series of field experiments was conducted to evaluate the effects of three chemicals--maleic hydrazide, naphthaleneacetic acid, and triiodobenzoic acid--in order to achieve one or more of the following objectives: 1) to increase the earliness of the crop, 2) to produce higher total yield, 3) to concentrate flowering into a shorter period to enhance the possibility of a single mechanical harvest. Gibberellic acid and indole acetic acid were also used in order to compare their effects as endogenous growth regulators with the preceding chemicals.

A series of greenhouse experiments was conducted to compare the effects of these three chemicals with indole acetic acid and gibberellic acid and their interactions on the physiology of growth and flowering of squash plants (Cucurbita pepo). These experiments were designed to establish, if possible, a hypothesis which could explain the role of these growth regulators in the physiology of sex expression in cururbits.

CHAPTER II

REVIEW OF LITERATURE

The experimental modification of sex expression essentially concerns individual ontogenies; otherwise it means the changes in flowering habits of individuals themselves. Sex expression of a flowering plant refers to the ability of such plant to produce one or more sex forms of flowers, their numbers, and positions on the plant.

Sex expression in cucurbits is a characteristic modified by genetic, environmental, and chemical factors. Tiedjens, in 1928 (101) was one of the earliest workers who directed his efforts to the study of sex expression in cucurbits. He considered earlier investigators of sex expression in plants in three groups: a group of investigators of sex inheritance who recognized only genetics as the determining mechanism, another group who claimed that environment is the basis of sex determination, and a third who took an intermediate position and considered the problem from several points of view.

Genetic Factors

In his theory about sex evolution in plants, Correns, in 1928 (in 106), assumed that the evolution of sexual types was from hermaphrodites to the intermediate forms, andromonoecious, trimonoecious, and gynomonoecious; thence to the extreme forms,

androecious, monoecious, and gynoecious. Every type of sex expression is represented in Cucurbitaceae. But, according to Yampolsky (113), the monoecious expression is the most common, the dioecious next, and the hermaphroditic is very rare.

As a result of crossing monoecious with andromonecious varieties of cucumber, cantaloupe, and watermelon, Rosa (93) concluded that the monoecious expression is dependent upon a single dominant genetic factor in all three species. Tiedjens (101) reported on a peculiar cucumber plant which was stunted in its growth and almost completely pistillate. This character seemed to be controlled by one recessive factor.

Whitaker's (107) survey of sex expression in 49 distributed varieties among eight species and four genera of cultivated Cucurbitaceae reported the following:

1. Each species is characterized by a specific qualitative type of sex expression.

2. Quantitative differences in sex expression may exist between varieties within a given species.

3. Staminate flowers are greatly in the majority at all times in all forms.

4. Some evidence exists for environmental control of sex expression.

Environmental Factors

Four variables of plant environment--nutrition, moisture, light regime, and temperature--may directly influence sex expression in plants.

Nutrition.--The evidence bearing upon the influence of mineral nutrition on sex expression is more substantial for monoecious species than for dioecious. As early as 1844, Heyer (44), working with sex ratio in monoecious cucumbers and pumpkins, found that the proportion of staminate to pistillate flowers could be changed materially by growing the plants in different soils. Tiedjens (101) reported that additional nitrogen increased the production of flowers of both sexes in cucumbers, with more increase in the pistillate flowers than in the staminate. Minina (71) found that periodic nitrogen fertilization favored femaleness while periodic application of potassium favored maleness in cucumbers. Hall (42) confirmed the effect of nitrogen on increasing the ratio of pistillate to staminate flowers in gherkins. Similar results were reported by Cunningham (25) in watermelons, Brantley (13) in cantaloupes and watermelons, and Hopp (47) in butternut squash.

Moisture.--Mining and Matzekevitch (77) reported that moisture conditions affected the onset of flowering in cucumbers. Low humidity accelerated the appearance of staminate flowers, while high humidity hastened the onset of pistillate flowers. They also observed that plants grown in moist or dry soils produced staminate and pistillate flowers simultaneously, but the appearance of

pistillate flowers was hastened under high soil moisture conditions.

Light Regime.--Tiedjens (101) demonstrated that exposing cucumber plants to a longer photoperiod increased the number of staminate flowers, while the number of pistillate flowers increased and the number of staminate decreased under reduced light conditions. Edmond (29) and Miller (70) reported that long days of high light intensity favored staminate flower production in cucumbers, whereas short days with low light intensity favored pistillate flowers. Similar effects were obtained by Nitsch (76) in squash and gherkins, by Ito and Saito (50 and 51) on Japanese cucumbers, by Brantley (13) on cantaloupes and watermelons, and by Galun (37) on cucumbers.

Temperature.--The work done by Nitsch (76), Wittwer and Hillyer (110), Ito and Saito (50 and 51), Fujieda (30) and others. indicated that high temperatures generally increased staminate flower production while low temperatures increased pistillate flower production. However, it should be noticed that temperature had a more profound effect during the dark period than during the light period. This explains the interaction between temperature and photoperiod in the results reported by many research workers (13, 29, 22, and 101).

Chemical Factors

Carbon Monoxide.--The earliest reports on chemical control of sex expression of cucumbers appear to have been obtained prior to 1938 by Russian workers (44). In 1938 Minina (71) found that treating cucumber plants during the seedling stage with wood-stove

gases modified their vegetative growth, increased the number of female flowers, and increased both fruit set and yield. In 1947, both Minina and Tylkina discovered that the effect is mainly due to the carbon monoxide in those gases (in 44). Similar results were reported by Czao (27).

Ethylene.--Nitsch (76) was not able to modify sex expression of acorn squash by exposure to ethylene in concentrations of 100 ppm for a period of 24 hours.

Acetylene.--Mehanik (69) reported that treating young cucumber plants with acetylene gas resulted in an increase in the number of female flowers, increase in the yield of fruits, and an advancement of maturity.

Methylene Blue.--Naugoljnyh (75) claimed that cucumber plants from seed treated with 0.03 percent solution of methylene blue for 24 hours at 22 to 25° C produced 62 percent more pistillate flowers and 45 percent more fruits. These were also heavier than controls, and resulted in 85 percent increase in the yield by weight.

Maleic Hydrazide.--Rehm (91) demonstrated that spraying watermelon seedlings with maleic hydrazide (MH) induced male sterility and increased femaleness of the plants. Wittwer and Hillyer (110) treated squash plants by dipping or spraying with MH solutions. Treatments resulted in plants that produced the usual number (eight to ten) of pistillate flowers in normal spatial arrangement with no staminate flowers. Similar results were also reported by Prasad and Tyagi (89) on bitter gourd, by Choudhury (22) on watermelons

and bottle gourds, and by Kali and Dhillon (55) on bottle gourds.

Triiodobenzoic Acid.--Wittwer and Hillyer (110), working with cucumbers, squash, and watermelons, showed that spraying the plants with triiodobenzoic acid (TIBA) reduced the male/female ratio by suppressing the development of staminate flowers. Irving and Zawawi (52) found that spraying cucumber and cantaloupe plants with 25 ppm of TIBA increased the number of female (100 to 200 percent) and male flowers but lowered male/female ratio. They also reported that application of TIBA to cucumbers at the onset of bloom increased the number of fruits but did not affect total yield. However, the same treatment increased both the number of fruit and total yield in cantaloupe.

Naphthaleneacetic Acid.--In a series of studies in 1950 and 1951, Laibach and Kribben (in 44) reported that application of naphthaleneacetic acid (NAA) or indoleacetic acid (IAA0 in 1 percent lanolin paste to cucumber plants 16 to 18 days old promoted the female and suppressed the male sex expression and decreased the total number of flowers formed on the plants. Nitsch (76) obtained similar results on acorn squash. He was able to lower the location of the first pistillate flower from the 20th to the 9th node by spraying the plants at the two-leaf stage with 100 ppm of NAA. Similar results on the effect of NAA on sex expression were reported by Wittwer and Hillyer (110) on cucumbers and squash, by Ito and Saito (48) on cucumbers, and by Brantley and Warren (13) on watermelons and cantaloupes.

Gibberellic Acid.--Wottwere and Bukovac (111), in 1958, were the first to report on the effect of gibberellic acid (GA0 on modifying flower-sex expression of cucumbers. They found that GA treatments consistently increased the number of staminate flowers preceding the first pistillate flower. Similar effects were also reported by Galun (36) in 1959. In 1960, Peterson and Anhder (83) were able to induce the formation of functional staminate flowers on completely female plants of the gynoecious cucumber line MSU 713-21. They also observed an increase in staminate flower production as the concentration and number of applications of GA increased.

Bukovac and Wittwer (17) demonstrated that foliar application of 100 ppm GA to young seedling of pickling-type cucumbers during two weeks of short-day exposure markedly reduced the effect of short photoperiod on hastening pistillate flower formation. They also reported that dipping the leaves of gynoecious cucumbers in 100 ppm GA solution induced the formation of staminate flowers. Long photoperiod enhanced the promotive effect of GA,not by increasing the number of nodes which produced staminate flowers, but by increasing the number of staminate flowers at each node.

Mitchell and Wittwer (73) reported that GA treatments of gynoecious cucumbers induced an uninterrupted sequence of staminate flowers from the second through the ninth nodes. Few plants produced mixed nodes "of pistillate and staminate flowers at the same node" immediately preceding the reversion to the pistillate phase. Similar effects of GA were reported by Hayase and Tanaka (43), Clark and Kenney (23), and Pike and Peterson (85 and 86) on gynoecious cucumber .

CHAPTER III

MATERIALS AND METHODS

Growth-Regulating Chemicals

Several chemicals which can change the sex of flowers have been reported. Three of these chemicals were selected according to their promise as efficacious modifiers. They are cheap, safe to handle, and represent three different families of chemical compounds. These three regulators were:

1. Maleic Hydrazide (MH).
2. Naphthaleneacetic Acid (NAA).
3. 2,3,5-Triiodobenzoic Acid (TIBA).

Two additional regulators, gibberellic acid and indoleacetic acid (GA and IAA, respectively), were used to compare their effects as endogenous plant hormones with other regulators and to study their interactions with other regulators.

Fresh chemical solutions were prepared by dispersing the growth regulating substance in surfactant, Triton X-100 (0.1 percent of the final concentration), and adding water. Chemicals were applied to foliage with a hand sprayer until the run-off point.

The research work of these studies consisted of two parts--a field phase and a greenhouse phase. The field phase was designed to evaluate the effect of the different treatments on

plant growth and development and determine the economic significance. The greenhouse phase was designed to reveal information on the role of these growth-regulating chemicals in the physiology of flowering and sex expression.

Field

All field work was conducted at Gainesville, Florida. The soil was classified as Kanapaha fine sand, and it was described as loose fine sand, acid, and low in organic matter.

The crops used were:

1. Cantaloupe--Cucumis melo 'Florida #1.'
2. Cucumber--Cucumis sativus 'Ashley.'
3. Summer squash--Cucurbita pepo 'Early Prolific Straightneck.'
4. Watermelon--Citrullus vulgaris 'Charleston Gray.'

A randomized complete-block design with four blocks (replicates) was used for all experiments. Treatments were arranged in single-row plots with each plot containing five hills of one plant each. Spacing distances used were 5 x 2 feet for squash, 5 x 3 feet for cucumbers, 6 x 4 feet for cantaloupes, and 9 x 5 feet for watermelons.

Fertilizer rates, method of cultivation, and insect and disease control were in accordance with the general practices for the North Central Florida area.

The field work was conducted during different seasons during the years of 1967 and 1968. These experiments can be described in

the following manner:

Time of application

The first set of experiments was started in March, 1967. Its purpose was to determine the best time of application of MH, NAA, and TIBA. A concentration of 100 ppm was selected from recommendations by other workers (46, 73, and 110). The treatments were 100 ppm each of MH, NAA, or TIBA. Each chemical was applied as a single spray at the two-leaf stage, a single spray at the four-leaf stage, or two sprays at the two- and at the four-leaf stage. These nine treatments plus a water control, each with Triton,were applied to cucumbers, squash, and watermelons.

Concentration

The second set of experiments was begun in March, 1968, to study the effect of different concentrations of each chemical. Concentrations used were 100, 150, and 200 ppm of MH and NAA, 25 and 50 ppm of TIBA, and the control treatments. Treatments were applied at the two-leaf stage to plants of cantaloupes, cucumbers, and watermelons.

The third set of experiments was conducted during the 1968 fall season on cantaloupes, cucumbers, and squash. Treatments were 100 and 200 ppm MH, 100 and 200 ppm of NAA, 25 ppm of TIBA, 100 ppm of GA, 100 ppm of IAA, a mixture of GA and IAA at 50 ppm each, and the control. The objectives of these experiments were to compare the effects of MH, NAA, and TIBA with GA and IAA on the plant growth and development and to evaluate the effects of these treatments on either earliness or concentration of the

yield into a shorter harvesting period.

An additional field experiment was conducted during the spring of 1969 to compare the effect of different regulators on plant growth and development of 'Zucchini' plants grown under greenhouse with those grown under field conditions. Plants were started in the greenhouse in peat pots. Chemicals were applied as a single spray at the four-leaf stage. Treatments were individual regulators or combinations of two. The concentration of each was 100 ppm. Plants were transplanted to the field one day after treatments, and measurements were taken on both vegetative and reproductive growth during the growing season.

All treatments were evaluated on the basis of the following criteria:

1. Vegetative growth as plant length, number of internodes, number of lateral branches developed on the plants, and the relative size of the plants as a percent of the control.

2. Flowering and sex expression by determining:
   a. The node position of the first staminate and pistillate flowers.
   b. The number of days from planting to anthesis of the first staminate and pistillate flowers.
   c. The number of staminate and pistillate flowers developed during the first two weeks of flowering.
   d. The female to male flower ratio.

3. Yield from five plants by number and weight of marketable fruits as graded as Fancy by the U. S. Standards. Cantaloupes and watermelons were harvested three times during a three-weeks' harvesting season. Cucumber and squash were harvested three times each week in the first experiment and once a week in the rest of the experiments for a harvest period of four weeks. Fruits harvested in the first week were considered as early yield for all crops.

Greenhouse

All greenhouse experiments were conducted on the University of Florida campus at Gainesville, Florida. Plants were grown in benches containing soil described as fine, loose sand, low in organic matter, with a pH around 6.5.

Squash was selected as an experimental standard plant for the following reasons:

1. Its development is fast.
2. It has a single dominant stem and no lateral shoots.
3. It is monoecious with a limited number of large flowers which can be identified and counted easily.

'Early Prolific Straightneck' summer squash was used in early experiments and Zucchini type in later ones. 'Zucchini'

hybrid plants were more uniform and produced single flower buds at each node.

Growth regulating chemicals were applied to the plants as seed soaking treatments or foliar spray with concentrations of 100 ppm. Seeds were soaked for 12 hours in Petri dishes on filter paper moistened with and floated on the solution of growth regulators. A small hand sprayer was used to apply foliar sprays. Seedling plants were sprayed at the four-leaf stage.

Seeds were sown either directly in bench soil or in peat pots for later transplanting to the benches. Fertilizer was supplied in two applications of complete fertilizer (6-8-8) at a rate equivalent to 900 pounds per acre. Soil moisture was kept near optimum, air temperature was between 60 and 80°F, and relative humidity averaged about 65 percent during the experimental period.

A randomized block design with four complete blocks was used for all experiments. Each plot within the block had dimensions of 1.5 x 1.5 feet and contained two plants. One plant was removed at the age of 21 days for fresh and dry weight determinations, and the other was left for 45 days to obtain flowering data.

Because of the limits in time and greenhouse space, different experiments were conducted in sequence. Experiments 1, 2, and 3 were conducted on 'Yellow Straightneck' to determine the effects of different regulators and their combinations, applied by soaking the seed and/or spraying the plants with aguous solution of 100 ppm, on plant growth and sex expression. Experiment 4 was conducted on 'Zucchini' using GA and IAA treatments applied as before. However, experiment 5 was designed to study the effect of spraying

the plants at the four-leaf stage with different regulators and their combinations on plant growth and sex expression.

Measurements and Evaluations

Treatment evaluations were based on the following determinations:

1. Length of the plant at 45 days after planting, as measured from the cotyledons to the apex.

2. Number of internodes at 45 days after planting counting beyond the cotyledons.

3. Number of male and female flower buds developed on plants.

4. Node position of all female flower buds.

5. Fresh and dry weight of plants at the age of 21 days after planting.

   a. The above-ground portion of the plant was harvested, cleaned from any attached dirt with a small brush, and weighed to determine the fresh weight per plant. Each plant was placed in a paper bag, dried in a forced-air oven at 68°C for 72 hours, and dry weight determined.

6. Total DNA and RNA contents of seedling plants, undifferentiated buds, male and female flower buds.

a. For the measurement of DNA and RNA, plant tissues were homogenized in an ice-cold Omni-Mixer for five minutes with 5 percent sucrose in 10^{-3} M.$MgCl_2$ and KCl solution, centrifuged and filtered through a glass wool pad to remove cell walls and other debris. Aliquots of the supernatant were used for analysis. Total DNA and RNA were determined by the Ogur and Rosen method (94). Nucleic acid was precipitated by adding perchloric acid (0.5M) to aliquots. The precipitate was washed by suspension and resedimentation in cold perchloric acid. Lipids and chlorophyll were removed by washing twice in an ether, ethanol, and chloroform mixture (2:2:1 V:V:V). The RNA was separated from DNA by adding 0.6 M KOH to the pellet and hydrolyzing for 18 hours at room temperature, then DNA was precipitated by adding perchloric acid. The absorbance of both DNA and RNA extracts was determined at 265 mu in a Beckman Du Spectrophotometer, and readings were referred to standard curves for obtaining quantitative amounts.

CHAPTER IV

RESULTS

Field

Effect of application time

Cucumber.--All treatments modified sex expression during the first two weeks of flowering either by increasing the number of pistillate flowers, decreasing the number of staminate flowers, or by both. Results of the spring 1967 experiment on cucumber are shown in Table 1. Maleic hydrazide increased the number of early pistillate flowers and early yield in terms of number and weight of fruits harvested. This indicates a direct correlation between the number of early fruit harvested as a result of maleic hydrazide treatment. However, such a relationship was not true in the case of NAA and TIBA. None of NAA treatments had any significant effect on yield. Treatments with TIBA at the two-leaf stage or at both two- and four-leaf stages suppressed both pistillate and staminate flower formation, decreased the total yield significantly, and there was no early yield. Treatments with TIBA at the four-leaf stage had no significant effect on pistillate flowers, decreased early yield, and had no significant effect on total yield.

Squash.--The results of the spring 1967 experiment show that MH at the two-leaf stage and TIBA at the four-leaf stage were the only two treatments which reduced the number of days to anthesis

and hastened the development of female flowers. All of the treatments increased the female/male flower ratio by reducing the number of male or increasing the number of female flowers developed on the plants during the first two weeks of flowering (Table 2).

Spraying the plants with 100 ppm of either MH or NAA at the two-leaf stage increased the early yield without any significant effects on total yield. Treatments of NAA at the four-leaf stage or at both the two- and four-leaf stage reduced the early yield.

All TIBA treatments, maleic hydrazide at the four-leaf stage and NAA at four-leaf stage treatments, decreased total yield in both number and weight of marketable fruits harvested.

Watermelon.--The spring 1967 results indicate that all treatments of MH decreased the number of days to anthesis, hastened the female flower development, and increased the total number of flowers. Treatments of NAA and TIBA delayed the flowering by either increasing the number of days to anthesis or decreasing the number of flowers developed in the first two weeks of flowering. However, early NAA and late TIBA sprays hastened female flower appearance (Table 3).

All treatments of MH and early treatment of NAA increased the early yield. However, total yield was increased by treatments with MH at four-leaf stage, and NAA at two-leaf stage, in terms of number and weight of fruits harvested. Treatment with NAA at four-leaf stage increased the weight of early fruits without affecting their number.

Treatment with TIBA at four-leaf stage increased the total number but not the weight of fruits harvested, due to smaller fruit size. The rest of TIBA treatments decreased both early and total yield.

Effects of concentrations

Cucumber.--The results of the spring 1968 experiment indicated that all of the treatments had inhibitory effects on vegetative growth as they decreased the length of main stem, internodes, and lateral branches (Table 4). Higher concentrations were more inhibiting than lower ones. Treatments of TIBA were more inhibiting than both maleic hydrazides and NAA. All concentrations of MH increased the number of laterals developed on the plants. On the contrary, 50 ppm of TIBA was sufficient to reduce laterals, dwarf the plants, and keep them at the rosette form for a period of more than three weeks after treatments.

All treatments lowered the node position of the first pistillate flower. All except 50 ppm TIBA hastened the appearance of early pistillate flowers, and the female/male flower ratio was increased by all treatments. Such increases in the ratio were caused by an increase in the number of pistillate flowers (100, 150, and 200 ppm MH, 100 ppm NAA, and 25 ppm TIBA) or a decrease of the number of staminate flowers (all treatments except 100 ppm maleic hydrazide) or by both (50 ppm TIBA).

Treatment with MH at 100 ppm was the only treatment to increase the number of early fruits and both fruit number and

weight of the total yield. The rest of the treatments reduced early yield, and that NAA 100 ppm, decreased the total yield.

Fall 1968 experimental results showed that treatment with GA did not affect the number of days before flowering. However, it did increase the number of male flowers developed during the first two weeks of flowering. Treatment with IAA induced early femaleness by decreasing the number of days before the first pistillate flower and increasing the number of pistillate flowers. A mixture of GA and IAA had an effect similar to that of IAA for total but not early pistillate flowers (Table 5).

Treatments with MH and TIBA had an effect on flowering similar to that of IAA. However, NAA treatments inhibited staminate flower development, and concentration of 200 ppm decreased both number of staminate and pistillate flowers.

Early yield was increased in number of fruits harvested by 100 and 200 ppm of MH and by GA + IAA mixture. However, it increased in weight by 100 ppm maleic hydrazide and GA + IAA mixture. Treatments with 100 ppm NAA, 25 ppm TIBA, and 100 ppm GA gave no early yield and decreased total yield.

Spraying the plants with 100 ppm maleic hydrazide, 100 ppm IAA, or a mixture of GA + IAA at 50 ppm of each, increased total yield in terms of both number and weight of marketable fruit harvested.

Squash.--The fall 1968 experimental results will show that IAA delayed male and hastened female flowers development, GA had an opposite effect, while a mixture of GA + IAA treatment delayed both male and female flower formation (Table 6).

Concentration of 100 ppm MH hastened the female flower development without affecting male flowers. However, 200 ppm of MH increased the number of days before the first male flower appearance. Both 100 and 200 ppm NAA treatments delayed male and female flower development and reduced the number of flowers considerably.

With regard to yield, MH 100 ppm was the only treatment to increase both early and total yield during the four weeks harvesting period. All other treatments except MH 200 ppm and IAA 100 ppm reduced or gave no early yield during the first week of harvest. Moreover, NAA at 200 ppm and GA 100 ppm reduced the total yield by more than 50 percent.

Watermelon.--All of the treatments reduced the length of main stem and the length of internodes, with more inhibitory effects from the higher concentrations. All concentrations of MH and TIBA and NAA at 100 ppm increased the number of lateral branches. However, the average length of laterals was less than the control in all treatments (spring 1968 results, Table 7).

All treatments changed sex expression during the first two weeks of flowering toward femaleness. They lowered the node position of the first female flower, hastened the appearance, and increased the number of female flowers developed on the plants.

Treatment with MH at 100 ppm increased both the early and the total yield. Concentrations of 150 ppm MH and 100 ppm NAA increased early yield slightly. While 25 ppm of TIBA had a non-significant increase in total yield, treatment with 50 ppm decreased the early yield.

Cantaloupe.--The results of the spring experiment on the effect of the different concentrations of MH , NAA, and TIBA on vegetative growth, sex expression, and yield are shown in Table 8.

Maleic hydrazide treatments reduced the size of plants by decreasing the length of the main stem, and the number and length of internodes. However, they had increased the number of laterals developed on the plants. Naphthaleneacetic acid treatments had similar effects on the size and length of plants but they did not affect the number of laterals. Triiodobenzoic acid treatments had more severe inhibitory effects on vegetative growth. And they also reduced or eliminated the development of laterals.

All of the treatments affected sex expression by reducing the number of days before the first female flower appearance and by increasing the female/male flower ratio. Such increase in the ratio was either the result of increasing the number of female flowers, reducing the number of male flowers, or a combination of both.

Treatments of 100 and 150 ppm of MH were the only ones to increase both early and total yield. Concentrations of 200 ppm of NAA and 50 ppm of TIBA gave no early yield, and instead delayed the fruit development to the later harvests. The rest of the treatments had no significant effect on the yield.

The results of the fall 1968 experiment help in comparing the effects of MH, NAA, and TIBA on cantaloupe plants with those of GA, IAA, and the control (Table 9).

Although both GA and IAA treatments had increased the size of the plants, GA increased the length of the plants while IAA decreased both number and length of internodes. Maleic hydrazide slightly inhibited the vegetative growth by reducing size of the plants and length of internodes but it increased the number of laterals. Both NAA and TIBA treatments severely inhibited the vegetative growth by reducing length of main stem, number of internodes, and number of lateriasl.

The treatments with MH, TIBA, and IAA had similar effects on sex expression. They hastened female flower development and increased the female/male flower ration.

Both NAA and TIBA reduced the number of male flowers. Gibberellic acid delayed the appearance of female flowers and increased the number of males.

Yield results indicate that while MH, TIBA, and IAA treatments had increased the total yield significantly, MH was the only treatment to increase earliness. Both NAA and TIBA decreased the early yield and tended to delay the harvest.

Greenhouse

The control treatments

'Yellow-Straightneck.'--Plants grown from seeds soaked in water produced a stem of about 15-16 cm. in length, an average of 10 internodes, 9 pistillate and 22 staminate flower buds per plant, at 45 days after planting (Tables 10 and 11).

'Zucchini.'--Plants grown from seed soaked in water had an average of about 13 internodes and 1.5 female flower bud per

plant with the first female carried at the tenth node position. A spray with GA at the four-leaf stage increased plant elongation and shifted sex expression slightly toward maleness. A spray with IAA had no significant effect on vegetative growth and shifted sex expression slightly toward femaleness (Table 12).

Gibberellic Acid

'Yellow-Straightneck.'--Gibberellic acid applied by soaking the seed in GA increased plant length, number of internodes, and shifted sex expression toward maleness. A subsequent spray with GA at the four-leaf stage increased plant length, number of internodes, maleness, and total number of flower buds over seed treatment alone. However, a subsequent spray with IAA decreased the effect of GA soaking on plant length, increased its effect on number of internodes, and shifted the sex expression slightly toward femaleness (Tables 10 and 11).

'Zucchini.'--Soaking seed in GA increased vegetative growth by increasing both plant length and number of internodes. It shifted sex expression toward maleness. A subsequent spray with GA had a more stimulating effect on vegetative growth and produced completely male plants. A subsequent spray with IAA tended to reduce the stimulating effect of GA. This spray with IAA reduced the effect of GA seed soaking on sex expression (Table 12).

Spraying the plant with GA increased plant length and both fresh and dry weight. However, percent dry weight was the same as the control. It slightly increased the male tendency of the plants and produced the first female flower buds at the 11th node position (Tables 13 and 14).

Indoleacetic Acid

'Yellow-Straightneck.'--Soaking the seed in IAA decreased plant length, shifted sex expression strongly toward femaleness, and increased the total number of flower buds developed on the plants. A subsequent spray with IAA at the four-leaf stage increased the inhibitory effect of seed treatment on vegetative growth and had a similar effect on sex expression. However, a subsequent spray of GA overcame completely and reversed the inhibition of seed soaking on vegetative growth and increased the number of male flower buds (Table 10).

'Zucchini.'--Indoleacetic acid applied by soaking the seed in IAA had very little effect on vegetative growth. It shifted sex expression toward femaleness. A subsequent spray with GA stimulated the vegetative growth and reversed the effect of IAA seed treatment on sex expression. However, a subsequent spray with IAA caused more inhibtion to plant length than IAA seed treatment alone. This spray caused more female tendency than either seed treatment or plant spray alone (Table 12).

Spraying the plants at the four-leaf stage with IAA decreased plant length, fresh and dry weight, and increased percent dry weight. This spray increased the number of female and decreased the number of male flower buds, causing a strong female tendency in sex expression.

Spraying with a mixture of GA plus IAA promoted vegetative growth by increasing both plant length, number of internodes, fresh and dry weight; however, it decreased precent dry weight. The

tendency toward femaleness in sex expression was less than IAA applied alone (Tables 13 and 14).

Maleic Hydrazide

'Yellow-Straightneck.'--Soaking the seed in MH inhibited vegetative growth by decreasing both plant length and the number of internodes. It also increased the number of female buds and decreased the number of male flower buds. A subsequent spray with GA completely overcame the effect of seed treatment with MH on plant length and sex expression, but had less effect than spraying with GA alone. A subsequent spray with IAA decreased the inhibition of MH seed treatment without affecting sex expression. However, spraying with IAA alone had a less inhibitory effect on vegetative growth and a more stimulating effect on flowering than MH seed soaking treatment and shifted sex expression toward femaleness (Table 10).

'Zucchini.'--Spraying the plants at the four-leaf stage with MH alone inhibited vegetative growth, decreased both fresh and dry weight, and increased percent dry weight. It also decreased the number of male and increased the number of female flower buds. Spraying with a mixture of MH and GA increased the number of internodes, decreased dry weight, but did not affect sex expression. However, spraying with a mixture of MH and IAA had more inhibitory effect on vegetative growth than MH alone. It also decreased fresh weight, dry weight, and percent dry weight, and increased female tendency (Tables 13 and 14).

Naphthaleneacetic Acid

'Yellow-Straightneck.'--Seed soaking in NAA decreased plant length, number of internodes and number of flower buds developed on the plants, with more inhibition of the male than female flower buds. A subsequent spray with GA decreased the inhibitory effect of NAA seed treatment on vegetative growth, but it had no effect on sex expression. A subsequent spray with IAA had an effect similar to that of GA (Table 11).

'Zucchini.'--Spraying the plants at the four-leaf stage with NAA or with a mixture of NAA plus GA or NAA plus IAA decreased the number of internodes. Spraying with NAA inhibited vegetative growth, decreased both fresh and dry weight, and increased the female tendency. A mixture of NAA plus GA increased plant length, decreased dry weight, and decreased the female tendency. A mixture of NAA plus IAA had an effect similar to that of NAA alone (Tables 13 and 14).

Triiodobenzoic Acid

'Yellow-Straightneck.'--Seed soaking in TIBA had a severe inhibitory effect on vegetative growth and reduced flowering by decreasing the number of male flower buds by more than 50 percent. This shifted sex expression toward femaleness. A subsequent spray with GA reduced the TIBA effect on plant length and increased the number of male flower buds over TIBA seed treatment alone. However, a subsequent spray with IAA reduced the inhibitory effect of TIBA on both plant length and number of internodes. This spray

increased both number of male and female flower buds over TIBA seed treatment alone (Table 11).

'Zucchini.'--All treatments of plant spraying with TIBA and its mixture with either GA or IAA had a severe inhibitory effect on the vegetative growth and decreasing both fresh and dry weights. Spraying the plants with a mixture of TIBA plus GA caused less inhibition than spraying with either TIBA alone or TIBA plus IAA. Treatment with TIBA increased the female tendency. However, the presence of GA in the spray decreased such effect, but the presence of IAA increased the female tendency of the plants (Tables 13 and 14).

Nucleic Acids

Results reported in Table 15 show nucleic acid contents of the whole plants, undifferentiated buds, female and male flower buds, and the effects of different seed soaking and plant spraying treatments with growth regulating chemicals on the amounts. These results can be summarized as follows:

1. Untreated female flower buds had higher contents of DNA and RNA than both undifferentiated and male flower buds. On the other hand, male flower buds had less DNA and more RNA contents than the undifferentiated ones.

2. Soaking the seeds in GA increased RNA contents of one week old seedlings, but had no effect on nucleic acid contents of older plants. Subsequent

spray with GA after seed soaking in water increased both DNA and RNA contents of the plants. Subsequent spray with GA after GA-seed soaking decreased DNA and increased RNA contents of the plants more than those soaked in GA alone. Subsequent spray with GA after IAA-seed soaking had similar effects.

3. Soaking the seeds in GA decreased DNA contents and increased RNA contents of undifferentiated buds. Subsequent plant spray with GA after seed soaking in water or GA decreased DNA and increased RNA contents of undifferentiated buds more than seed soaking alone. However, subsequent plant spray with GA after IAA-seed soaking increased RNA contents.

4. Soaking the seeds in IAA increased DNA contents of young seedling, but had no effect on older plants. Spraying the plants produced from water-soaked seed with IAA increased their contents of both DNA and RNA. Plants which were produced from either GA-soaked seed or IAA-soaked seed had higher RNA contents when sprayed with IAA than those unsprayed.

5. Soaking the seeds in IAA increased RNA contents of undifferentiated flower buds more than soaking in water. Subsequent plant spray with IAA after seed soaking in either water or IAA increased RNA content of undifferentiated buds. On the other hand, subsequent plant spray with IAA after seed soaking in GA increased both DNA and RNA contents of the undifferentiated buds.

6. Seed soaking in MH increased DNA contents of young seedlings, but had no effect on the older plants.

7. Soaking the seeds in NAA decreased RNA content of younger seedlings, and both RNA and DNA contents of older plants.

8. Seed soaking in TIBA decreased DNA and RNA contents of both young seedlings and older plants.

9. Seed soaking in MH or TIBA increased RNA contents of undifferentiated flower buds, but had no significant effects on DNA contents. Seed soaking in NAA had no significant effect on nucleic acid contents of the undifferentiated flower buds.

10. The female flower buds did not show any significant differences in their DNA contents as a result of the different treatments. However,

they had lower RNA contents as a result of seed soaking treatments in GA, MH, or NAA.

11. All GA-seed soaking treatments increased RNA contents of the male flower buds. Seed soaking in MH or NAA decreased RNA contents of female buds. Soaking the seeds in TIBA decreased both DNA and RNA contents of the female flower buds.

TABLE 1

FLOWER SEX EXPRESSION AND MARKETABLE YIELD OF CUCUMBER GROWN IN SPRING 1967 IN RESPONSE TO CHEMICAL REGULATORS AND THEIR APPLICATION TIME*

				MH 100 ppm			NAA 100 ppm			TIBA 100 ppm			L.S.D.
			Check	2 L	4 L	2+4 L	2 L	4 L	2+4 L	2 L	4 L	2+4 L	5%
Flower Sex Expression	Days to Anthesis		37.0	37.0	38.0	36.0	38.0	36.0	40.0	45.0	37.0	46.0	
Number of flowers per plant	First Week	♀	0.0	0.7	1.0	1.0	1.8	1.0	0.8	0.1	0.4	0.0	0.3
		♂	6.8	9.0	11.0	11.3	3.5	9.0	1.2	0.4	5.0	0.3	1.6
	Total of 2 Weeks	♀	3.3	5.7	5.7	5.0	3.8	7.6	3.2	0.4	3.4	0.5	0.9
		♂	28.4	21.5	26.0	26.3	12.6	22.2	8.6	3.6	19.0	3.3	3.1
		♀+♂	31.7	27.2	31.7	31.3	16.4	29.8	11.8	4.0	27.4	4.2	6.3
Marketable Yield													
Fruits harvested per five plants	No. of Fruits	Early	6.0	9.0	9.0	8.0	5.5	5.0	5.0	0.0	3.0	0.0	1.5
		Total	55.0	53.0	58.0	52.0	58.0	58.0	51.0	39.0	48.0	32.0	8.3
	Weight in lbs.	Early	4.2	6.0	5.4	4.2	3.8	3.4	3.6	0.0	1.1	0.0	1.0
		Total	38.3	33.8	42.8	33.8	36.0	35.7	33.8	21.4	30.4	18.4	11.0

*Plants sprayed at 2L= two leaf stage, at 4L = four-leaf stage, and at 2+4L= two- and four-leaf stage.

TABLE 2

FLOWER SEX EXPRESSION AND MARKETABLE YIELD OF SQUASH GROWN IN SPRING 1967 IN RESPONSE TO CHEMICAL REGULATORS AND THEIR APPLICATION TIME*

				MH 100 ppm			NAA 100 ppm			TIBA 100 ppm			L.S.D.
			Check	2L	4L	2+4L	2L	4L	2+4L	2L	4L	2+4L	5%
Flower Sex Expression	Days to Anthesis		40	38	40	41	40	42	42	40	38	40	
Number of flowers per plant per two weeks of flowering	First Week	♀	2	4	3	3	3	2	1	2	4	2	1.3
		♂	6	4	3	3	3	4	2	1	2	1	2.5
	Total of 2 Weeks	♀	8	11	8	8	8	9	8	7	9	8	1.7
		♂	15	11	12	12	11	10	10	13	15	13	4.5
		♀+♂	23	22	20	20	19	19	18	20	24	21	3.3
Marketable Yield													
Fruits harvested per five plants	No. of Fruits	Early	12	20	16	15	19	5	7	9	14	13	4.1
		Total	60	62	48	51	56	50	57	47	47	48	7.6
	Weight in lbs.	Early	4.5	8.7	6.3	5.8	8.0	1.9	2.4	3.5	5.1	4.2	2.3
		Total	22.6	23.8	17.3	18.6	20.8	17.4	19.8	17.5	17.8	18.4	4.5

* Plants sprayed at 2L = two-leaf stage, at 4L = four-leaf stage, and at 2+4L = two- and four-leaf stage.

TABLE 3

FLOWER SEX EXPRESSION AND MARKETABLE YIELD
OF WATERMELON GROWN IN SPRING 1967 IN RESPONSE TO
CHEMICAL REGULATORS AND THEIR APPLICATION TIME*

				MH 100 ppm			NAA 100 ppm			TIBA 100 ppm			L.S.D.
			Check	2 L	4 L	2+4 L	2 L	4 L	2+4 L	2 L	4 L	2+4 L	5%
Flower Sex Expression	Days to Anthesis		43.0	41.0	42.0	42.0	43.0	46.0	48.0	45.0	45.0	47.0	
Number of flowers per plant	First Week	♀	0.0	1.0	0.5	0.0	0.6	.3	0.0	0.0	.5	0.0	0.3
		♂	6.0	7.0	5.5	4.0	4.7	4.1	2.4	3.0	6.3	0.0	1.8
	Total of 2 Weeks	♀	1.1	2.6	1.1	1.8	1.1	1.0	0.6	0.3	1.0	0.1	0.7
		♂	14.1	18.0	18.2	16.0	12.2	10.3	7.4	10.3	12.4	9.4	2.3
		♀+♂	15.2	20.6	19.3	17.8	13.3	11.3	8.0	10.6	13.4	9.5	4.1
Marketable Yield													
Fruits harvested per five plants	No. of Fruits	Early	2.4	3.5	3.5	3.3	3.3	2.4	2.0	0.8	0.9	0.0	0.7
		Total	7.2	7.2	8.9	7.8	8.9	7.7	7.7	5.1	9.1	6.4	0.5
	Weight in lbs.	Early	62.0	91.0	115.0	83.0	93.0	108.0	54.0	21.0	23.0	00.0	1.2
		Total	182.0	179.0	230.0	181.0	218.0	191.0	181.0	119.0	158.0	144.0	3.4

*Plants sprayed at 2L = two-leaf stage, at 4L = four-leaf stage, and at 2+4L = two- and four-leaf stage.

TABLE 4

EFFECTS OF CHEMICAL REGULATORS AND DIFFERENT CONCENTRATIONS ON VEGETATIVE GROWTH, FLOWER SEX EXPRESSION AND MARKETABLE YIELD OF CUCUMBER GROWN IN SPRING 1968

			Check	MH 100	MH 150	MH 200ppm	NAA 100	NAA 150	NAA 200ppm	TIBA 25	TIBA 50ppm	L.S.D. 5%
Vegetative Growth	Length of Main Stem (in.)		22.9	19.3	17.4	16.0	20.4	17.8	13.6	15.8	10.3	2.7
Three Weeks After Treatments	Ave. Length of Internodes (in.)		3.7	3.4	3.2	3.0	3.4	3.4	3.1	2.4	1.4	0.2
	Number of Laterals per Plants		2.3	4.3	4.0	3.3	3.3	3.0	1.7	2.3	0.3	0.7
	Ave. Length of Laterals (in.)		8.5	8.0	5.8	4.9	7.1	7.1	5.1	3.8	0.8	0.6
Flower Sex Expression	Node Range of 1st Flower		8-10	4-5	4-5	3-5	3-5	3-5	3-4	3-5	---	
Number of Flowers per Plant	First Week	♀	0.0	1.0	1.2	1.5	1.7	1.7	1.4	1.0	0.2	0.3
		♂	8.0	10.5	9.2	6.0	5.0	4.5	2.0	9.0	0.0	2.7
	Total of 2 Weeks	♀	6.0	10.0	9.2	8.9	8.2	6.7	5.4	8.0	2.7	1.3
		♂	40.0	37.5	33.2	28.0	19.0	17.5	12.4	31.0	14.0	5.6
		♀+♂	46.0	47.5	42.4	36.9	27.2	24.2	17.8	39.0	16.7	7.1
Marketable Yield	No. of Fruits	Early	8.0	12.0	5.0	2.0	5.0	3.0	0.0	4.0	0.0	1.8
		Total	75.0	83.0	65.0	58.0	71.0	62.0	28.0	63.0	26.0	3.3
Fruits Harvested per five plants	Weight in Pounds	Early	5.3	5.3	2.5	0.9	2.5	1.6	0.0	1.6	0.0	2.1
		Total	49.7	56.0	46.6	38.5	40.7	41.6	13.5	38.7	11.7	5.3

TABLE 5

THE INFLUENCE OF CHEMICAL REGULATORS AND CONCENTRATIONS ON FLOWER SEX EXPRESSION AND MARKETABLE YIELD OF CUCUMBER GROWN IN FALL 1968

				MH		NAA		TIBA	GA	IAA	GA + IAA	L.S.D.
			CHECK	100 ppm	200 ppm	100 ppm	200 ppm	25 ppm	100 ppm	100 ppm	50 @ ppm	5%
Flower Sex Expression												
	Days from Planting to the Appearance of First:	♂	36	34	37	39	41	34	35	37	36	
		♀	44	39	41	40	42	36	44	40	42	
	Number of flowers per plant	1st Week ♀	0	3	2	2	1	2	0	3	0	0.5
		1st Week ♂	9	10	7	6	3	9	12	10	5	1.3
		Total of 2 Weeks ♀	7	13	10	11	5	9	6	13	12	1.6
		Total of 2 Weeks ♂	32	38	30	23	16	30	40	32	29	7.0
		Total of 2 Weeks ♀+♂	39	51	40	34	21	39	46	45	41	8.3
Marketable Yield												
	Fruits harvested per five plants	No. of Fruits Early	2	7	5	3	0	0	0	4	5	2.3
		No. of Fruits Total	38	53	42	44	30	30	28	46	45	6.6
		Weight in Pounds Early	1.8	4.6	3.0	1.7	0.0	0.0	0.0	2.6	3.2	1.3
		Weight in Pounds Total	25.0	34.3	26.8	25.6	17.3	15.2	18.0	30.7	30.8	4.6

TABLE 6

THE INFLUENCE OF CHEMICAL REGULATORS AND CONCENTRATIONS ON FLOWER SEX EXPRESSION AND MARKETABLE YIELD OF SQUASH GROWN IN FALL 1968

			Check	MH 100 ppm	MH 200 ppm	NAA 100 ppm	NAA 200 ppm	TIBA 25 ppm	GA 100 ppm	IAA 100 ppm	GA + IAA 50 ppm	L.S.D. 5%
Flower Sex Expression												
Days from planting to the appearance of first:		♀	37.0	35.0	37.0	39.0	42.0	36.0	43.0	35.0	38.0	
		♂	35.0	35.0	38.0	40.0	43.0	36.0	39.0	38.0	38.0	
Number of flowers per plant	First Week	♀	2.8	4.2	3.0	1.6	0.0	2.4	.6	3.4	1.0	0.6
		♂	4.4	3.9	3.5	.8	0.0	2.0	3.7	1.3	1.6	1.3
	Total of 2 Weeks	♀	5.8	7.7	6.0	5.3	3.6	5.4	3.3	6.3	5.3	1.4
		♂	8.5	7.8	7.4	5.1	4.1	5.0	9.1	6.1	6.6	1.3
		♀ + ♂	14.3	15.5	13.4	10.4	7.7	10.4	12.4	12.4	11.9	3.6
Marketable Yield												
Fruits harvested per five plants	No. of Fruits	Early	2.3	6.0	1.8	0.0	0.0	0.5	0.0	3.0	0.0	0.8
		Total	23.0	33.8	23.8	19.3	17.3	20.0	12.5	26.3	22.0	3.7
	Weight in Pounds	Early	1.6	4.5	1.4	0.0	0.0	0.2	0.0	2.4	0.0	1.0
		Total	14.5	23.9	15.3	11.5	6.2	12.5	7.9	17.9	15.1	3.7

TABLE 7

EFFECTS OF CHEMICAL REGULATORS AND DIFFERENT CHEMICAL CONCENTRATIONS ON VEGETATIVE GROWTH, FLOWER SEX EXPRESSION, AND MARKETABLE YIELD OF WATERMELON GROWN IN SPRING 1968

			MH			NAA			TIBA		L.S.D.
		Check	100	150	200 ppm	100	150	200 ppm	25	50 ppm	5%
Vegetative Growth	Length of Main Stem (in.)	25.6	21.3	18.7	18.3	21.6	21.1	20.6	20.1	17.8	1.8
Three Weeks After Treatments	Ave. Length of Internodes (in.)	4.9	4.4	4.0	3.9	4.3	3.8	3.6	3.5	2.9	
	No. of Laterals per Plant	2.3	3.7	4.0	3.3	3.3	2.6	2.6	4.0	3.3	0.9
	Ave. Length of Laterals (in.)	12.3	10.6	9.9	8.3	9.7	8.9	8.0	6.3	6.3	1.4
Flower Sex Expression	Node Range of 1st Flower	12-15	7-10	6-10	6-9	7-9	7-0	6-9	6-10	7-10	
Number of Flowers per Plant	First Week ♀	0.0	1.8	1.4	.8	1.7	1.4	1.7	1.0	.4	0.5
	First Week ♂	5.2	4.2	4.0	3.3	4.4	3.8	2.7	4.1	1.7	2.1
	Total of 2 Weeks ♀	1.2	5.7	4.4	3.3	5.5	5.2	4.2	3.1	1.5	0.8
	Total of 2 Weeks ♂	14.2	12.7	11.3	9.5	12.0	11.9	9.3	12.5	8.1	3.6
	Total of 2 Weeks ♀ + ♂	15.4	18.4	15.7	12.8	17.5	17.1	13.5	15.6	9.6	2.6
Marketable Yield	No. of Fruits Early	2.0	4.0	3.0	2.5	3.0	1.5	2.5	2.5	1.0	0.8
	No. of Fruits Total	5.5	7.8	6.0	5.8	6.0	5.5	4.5	6.3	5.3	1.2
Fruits Harvested per five Plants	Weight in lbs. Early	54.0	105.0	76.0	72.0	81.0	43.0	58.0	73.0	26.0	2.5
	Weight in lbs. Total	127.0	177.0	140.0	142.0	142.0	125.0	96.0	143.0	111.0	4.3

TABLE 8

EFFECTS OF CHEMICAL REGULATORS AND DIFFERENT CONCENTRATIONS
ON VEGETATIVE GROWTH, FLOWER SEX EXPRESSION, AND MARKETABLE YIELD
OF CANTALOUPE GROWN IN SPRING 1968

				MH			NAA			TIBA		L.S.D.
			Check	100	150	200ppm	100	150	200ppm	25	50ppm	5%
Vegetative Growth	Length of Main Stem (in.)		41.0	35.0	32.0	30.0	35.0	30.0	27.0	13.0	8.0	3.4
Three weeks after treatment	No. of Internodes		23.0	21.0	20.0	19.0	20.0	18.0	17.0	11.0	9.0	1.8
	Ave. Length of Internode (in.)		1.8	1.7	1.6	1.6	1.8	1.7	1.6	1.2	0.9	0.1
	No. of Laterals per plant		2.5	4.0	4.0	3.5	2.0	1.8	1.5	1.0	0.0	0.8
	Relative Size of plant		100.0	85.0	75.0	70.0	80.0	80.0	70.0	70.0	55.0	
Flower Sex Expression	Days before 1st flower		43.0	38.0	40.0	40.0	40.0	40.0	42.0	37.0	36.0	
Number of flowers per plant	First Week	♀	0.6	1.3	1.1	1.4	0.9	0.9	0.9	1.1	1.2	0.3
		♂	5.9	5.1	4.4	3.7	6.2	4.0	4.5	4.9	3.0	1.1
	Total of 2 Weeks	♀	1.9	2.8	2.4	2.7	2.4	2.0	2.2	2.3	2.0	0.5
		♂	10.3	8.3	6.7	6.1	8.3	5.6	5.7	7.4	4.4	1.6
		♀+♂	12.2	11.1	9.1	8.8	10.7	7.6	7.9	9.7	6.4	1.4
Marketable Yield Fruits harvested per five plants		Early	1.3	4.0	2.8	1.0	0.8	1.0	0.0	1.3	0.0	1.1
		Total	13.8	17.0	17.0	16.5	13.0	13.3	11.3	14.3	12.8	3.1

TABLE 9

THE INFLUENCE OF CHEMICAL REGULATORS
ON VEGETATIVE GROWTH, FLOWER SEX EXPRESSION, AND MARKETABLE YIELD
OF CANTALOUPE GROWN IN FALL 1968

			Check	MH 100ppm	NAA 100ppm	TIBA 25ppm	GA 100ppm	IAA 100ppm	L.S.D. 5%
Vegetative Growth	Length of Main Stem (in.)		39.3	36.5	19.8	9.3	45.5	32.5	4.5
Two Weeks After Treatments	No. of Internode per M. Stem		20.3	20.5	15.0	11.3	20.0	18.3	2.1
	Ave. Length of Internode (in.)		2.0	1.8	1.3	0.8	2.3	1.8	0.1
	No. of Laterals per Plant		2.0	3.8	1.3	0.0	1.8	2.3	1.3
	Relative Size of Plants		100.0	90.0	80.0	55.0	110.0	120.0 %	
Flower Sex Expression	Days Before First Flower		42.0	37.0	45.0	38.0	46.0	36.0	
Number of Flowers per Plant	First Week	♀	0.0	0.5	0.0	0.2	0.0	0.6	0.3
		♂	6.3	4.4	0.0	2.3	9.3	6.8	2.2
	Total of 2 Weeks	♀	1.9	3.3	1.3	1.9	1.2	2.9	0.6
		♂	15.9	16.5	7.7	8.6	19.6	18.8	3.5
		♀ + ♂	17.8	19.8	9.1	10.5	20.8	21.7	2.8
Marketable Yield	Fruits Harvested per Five Plants	Early	5.0	11.0	2.0	0.0	4.0	7.8	2.9
		Total	13.3	20.8	13.3	16.3	12.5	18.0	1.8

TABLE 10

THE INFLUENCE OF THE DIFFERENT REGULATORS AND THEIR INTERACTION ON VEGETATIVE GROWTH AND SEX EXPRESSION OF YELLOW STRAIGHTNECK SQUASH

TREATMENTS		VEGETATIVE GROWTH		SEX EXPRESSION		
Seed Soaked in	Plants Sprayed with	Plant Length in cm	Number of Internodes per Plant	Average Number of Flower Buds Developed per Plant		
				♀	♂	Total
EXPERIMENT 1:						
H_2O		15.0	9.5	9.5	22.0	31.5
GA	----	31.1	10.8	4.0	28.0	32.0
GA	GA	42.1	13.3	3.0	32.5	35.5
GA	IAA	28.7	12.5	11.0	21.0	33.0
IAA	----	10.9	9.8	17.5	19.0	36.5
IAA	IAA	10.4	8.3	15.5	18.0	33.5
IAA	GA	23.4	10.5	13.5	24.0	37.5
EXPERIMENT 2:						
H_2O	----	14.5	10.0	8.3	21.5	29.8
H_2O	GA	20.3	9.0	4.8	24.5	29.3
H_2O	IAA	13.3	10.8	16.3	20.3	36.6
MH	----	9.5	8.5	10.5	16.3	26.8
MH	GA	14.3	8.5	7.0	22.3	29.3
MH	IAA	10.8	12.5	10.5	16.3	28.8
L.S.D. 5% Level		1.6	0.8	1.2	2.5	1.8

TABLE 11

VEGETATIVE GROWTH AND SEX EXPRESSION
OF YELLOW STRAIGHTNECK SQUASH IN RESPONSE TO TREATMENTS
WITH CHEMICAL REGULATORS

TREATMENTS		VEGETATIVE GROWTH		SEX EXPRESSION		
Seed Soaked in	Plants Sprayed with	Plant Length in cm	Number of Internodes per Plant	Average Number of Flower Buds Developed per Plant		
Experiment 3:				♀	♂	Total
H_2O		16.0	9.0	8.0	21.0	29.0
GA		30.0	9.8	5.0	24.0	29.0
GA	IAA	25.0	10.3	7.0	23.0	30.0
IAA		16.0	11.0	17.0	20.0	37.0
IAA	GA	20.0	11.5	16.0	23.0	39.0
NAA		11.0	6.5	7.0	11.0	18.0
NAA	GA	16.0	7.5	7.0	12.0	19.0
NAA	IAA	14.0	8.5	7.0	11.0	18.0
TIBA		7.0	6.3	8.0	10.0	18.0
TIBA	GA	14.0	6.5	7.0	13.0	20.0
TIBA	IAA	12.0	8.0	11.0	12.0	22.0
L.S.D. 5% Level		1.2	.6	1.4	2.0	2.1

TABLE 12

EFFECTS OF THE DIFFERENT CHEMICAL REGULATORS
AND THEIR INTERACTION ON
VEGETATIVE GROWTH AND SEX EXPRESSION
OF ZUCCHINI SQUASH

TREATMENTS		VEGETATIVE GROWTH		SEX EXPRESSION		
Seed Soaked in	Plants Sprayed with	Plant Length in cm	Number of Internodes per Plant	Average Number of Flower Buds Developed per Plant		
Experiment 4:				♀	♂	Total
H_2O		20	12.8	1.5	11.3	12.8
H_2O	GA	24	13.3	0.3	13.0	13.3
H_2O	IAA	21	13.3	2.5	11.0	13.3
GA		40	14.5	0.5	14.0	14.5
GA	GA	59	15.0	0.0	17.5	17.5
GA	IAA	31	12.5	1.0	11.5	12.5
IAA		18	11.8	2.8	9.0	11.8
IAA	GA	30	13.8	1.5	12.3	13.8
IAA	IAA	15	11.8	3.3	8.5	11.8
L.S.D. 5% Level		1.3	.7	.6	1.2	1.2

TABLE 13

EFFECTS OF THE DIFFERENT CHEMICAL REGULATORS
AND THEIR INTERACTIONS ON
VEGETATIVE GROWTH AND SEX EXPRESSION
OF ZUCCHINI SQUASH

TREATMENTS	VEGETATIVE GROWTH		SEX EXPRESSION			
Plant Sprayed at the four-leaf stage with	Plant Length in cm	Number of Internodes per Plant	Average Number of Flower Buds Developed per Plant			Node Pos. First Female
			♀	♂	Total	
Experiment 5:						
WATER (Control)	14.7	9.3	2.0	9.0	11.0	10
GA	23.3	9.7	1.5	9.5	11.0	11
IAA	12.3	9.0	4.5	5.3	9.8	7
GA + IAA	17.5	10.7	2.8	7.3	10.0	7
MH	9.5	8.3	3.0	7.5	10.5	8
MH + GA	15.3	11.7	2.5	9.5	12.0	9
MH + IAA	9.0	7.7	4.0	5.0	9.0	6
NAA	12.8	8.3	3.3	6.8	10.0	8
NAA + GA	15.5	8.7	2.8	7.8	10.5	10
NAA + IAA	13.0	7.7	4.0	5.3	8.3	9
TIBA	8.0	8.3	3.8	6.8	10.5	7
TIBA + GA	13.1	8.7	2.3	7.8	10.0	9
TIBA + IAA	9.3	7.3	4.3	5.3	9.5	6
L.S.D. 5% Level	0.9	0.5	0.7	1.4	1.2	

TABLE 14

FRESH AND DRY WEIGHTS OF ZUCCHINI SQUASH PLANTS
IN RESPONSE TO THE DIFFERENT
CHEMICAL REGULATORS

TREATMENTS Plants Sprayed at the Four-leaf Stage with	FRESH AND DRY WEIGHT OF PLANTS Two Weeks After Treatment		
	Fresh Weight gm./Plant	Dry Weight gm./Plant	Percent Dry Weight
WATER (Control)	253	16.7	6.58
GA	303	17.2	5.66
IAA	220	15.4	7.00
GA+IAA	300	17.1	5.70
MH	203	16.2	7.96
MH + GA	230	16.7	7.24
MH + IAA	193	15.5	8.01
NAA	190	12.9	6.76
NAA + GA	238	13.6	5.69
NAA + IAA	218	13.2	6.06
TIBA	170	12.2	7.15
TIBA + GA	225	13.6	6.02
TIBA + IAA	203	13.0	6.40
L.S.D. 5% Level	24	0.4	0.32

TABLE 15

THE INFLUENCE OF THE DIFFERENT CHEMICAL REGULATORS
ON NUCLEIC ACID CONTENTS OF
SUMMER SQUASH PLANTS AND FLOWER BUDS

Treatments		Nucleic Acid Contents in mg./gm. Fresh Weight of:									
Seed Soaked in	Plants Sprayed with	Plants Before Spraying		Plants 2 Weeks after Spraying		Flower Buds Undifferentiated		Female		Male	
		DNA	RNA	DNA	RNA	DNA	RNA	DNA	RNA	DNA	RNA
H_2O		.120	.272	.169	.312	.253	.596	.277	.732	.187	.678
H_2O	GA			.206	.343	.210	.642	.256	.751	.179	.728
H_2O	IAA			.210	.368	.235	.645	.280	.770	.200	.692
GA		.112	.304	.190	.329	.217	.662	.263	.646	.181	.729
GA	GA			.160	.353	.196	.685	.259	.733	.178	.749
GA	IAA			.177	.377	.243	.697	.279	.736	.205	.715
IAA		.131	.277	.181	.320	.235	.691	.270	.727	.188	.688
IAA	GA			.155	.361	.225	.705	.270	.738	.178	.712
IAA	IAA			.179	.339	.241	.662	.279	.745	.197	.636
MH		.149	.211	.152	.312	.263	.630	.269	.678	.177	.591
NAA		.117	.202	.129	.287	.257	.587	.262	.686	.169	.631
TIBA		.136	.150	.134	.256	.267	.634	.277	.709	.148	.556
L.S.D. 5% Level		.008	.036	.024	.019	.020	.023	.027	.041	.021	.036

CHAPTER V

DISCUSSION

General

The results of these studies indicated that each of the growth regulators used had a profound effect not only on flower sex expression, but also on plant growth and fruit growth and development. In order to discuss these results, a description of vegetative growth, flowering, and fruiting habits of the crops used must be mentioned.

A great number of research papers report on either flowering or fruiting habits of cucurbits, but there is little descriptive information on the overall plant growth and development of these crops or other economic crops.

Three of the crops used in these studies, namely cantaloupe, cucumber, and watermelon, are alike in their vegetative growth habits. They have a main stem from which arise lateral branches, "primary branches," at the basal nodes. Several secondary shoots arise from the lateral branches. Squashes used in these studies were of the bush type which differ from the previous crops by their much shortened internodes and lack of lateral branching.

Flowers in these crops are borne singly or in clusters in the axils of the leaves. The sequence of floral production has been studied by many researchers (19, 25, 26, 42, 76, 101, and 107). They showed that as the vine progresses in its development, sex expression

undergoes a gradual change from strongly staminate to strongly pistillate phases. Such change can be measured qualitatively as sex of the flower produced and quantitatively in terms of the ratio between staminate and pistillate flowers.

Fruit setting in cucurbits has been the subject of several investigators such as Bushnell (19), Cunningham (25), McGlasson (67), Porter (88), Rosa (93), and Tiedjens (101). They have reported cyclic setting of fruits which followed the production of pistillate flowers in a cyclic time and pattern. The cycle of fruit setting consisted of alternative setting and nonsetting periods with the length and frequency of these periods varying with species, environment, and physiological conditions.

In the light of the previous studies, as well as the results of the present investigation, a schematic figure is presented here to illustrate the relationships between the different stages of plant growth and development of the cucurbitaceae.

Illustrations in Figure 1 represent the chronological relationships of the different developmental stages which resulted from superimposing the different curves of vegetative growth, flowering, fruit setting, and fruit growth. These curves are general and can be applied to any of the crops used in this study; however, the size of the curves and their units might be changed with a particular crop.

During its development from seed to maturity the cucurbit plant exhibits a double sigmoid growth curve. Within a normal growing season there are three different and distinctive phases:

First: A period of strictly vegetative growth which lasts for about six weeks after planting. This period is characterized by a fast, uniform rate of growth, development of lateral branches, and ends with flower initiation.

Second: A period of standstill in new vegetative growth which lasts for two weeks and is characterized by the beginning of the flowering phase and the occurrence of early flowering and fruiting cycles. Hall (42) stated, "the period between the origin of flower primordia and syngamy was characterized in all series by diminished differentiation of new vegetative organs. During this period, however, there occurred the maximum gains in leaf area and internode elongation. On the whole, it was also a period of low water and salt intake." The first fruit setting cycle takes place at the end of this period; however, both resurgence of vegetative growth and formation of early fruit take place at the same time (42).

Third: A period of acceleration in both vegetative and reproductive growth. In this period there is a large competition for food materials between vegetative parts, developing fruits, flower formation, and newly fertilized ovaries. Such competition plays an important role in crop production, not only on the number of fruit produced but also on their quality and harvest date.

Porter (88) reported that weakly growing runners resulted in poor fruit set in watermelon. Wolf and Hartman (77) were able to increase the percentage of fruit set by restricting the vegetative growth of muskmelons with various types of pruning. On the other

hand, Cunningham (25) and Nylund (79) found that leaf pruning caused a quantitative decrease in fruit set.

Various reports have indicated that the growth of individual cucurbit fruit follow a sigmoid curve (7, 59, 67, 77, 82, 90, and 108). Final fruit size in cucurbits depends on both rate of growth and duration during the exponential phase. When the exponential rate is high, final size is attained earlier. This illustrates the importance of the balance between vegetative and fruit growth during this period.

Vegetative Growth

The results of these studies are in accordance with the previous reports (2, 7, 12, 13, 32, 39, 41, 46, 115, and 116) on the effects of the regulators used on the vegetative growth of plants. The observations made during the first experiments indicated that each of the main regulators used--namely MH, NAA, and TIBA--had inhibitory effects on plant growth. Those effects were different with different treatments and different crops.

In general, plants treated with MH were less inhibited in their growth and recovered faster than those treated with NAA and TIBA. Double sprays of these regulators were more inhibitive than single spray treatments.

In all of the crops used in these studies--cantaloupe, cucumber, squash, and watermelon--measurements three weeks after treatment indicated that the concentrations used of MH, NAA, TIBA, and IAA inhibited vegetative growth through decreasing both the length and the number of internodes of the main stem. Gibberellic acid increased

both the number and the length of internodes of the main stem (Tables 4, 5, 6, 7, 8, and 9).

Maleic hydrazide was the most effective regulator in breaking apical dominance. It increased the number of lateral branches in cucumber, cantaloupe, and watermelon; however, it slightly decreased their length. These are typical effects of MH on the growth of many plants (115 and 116).

Although the results show that TIBA inhibited lateral development, it must be mentioned that plants treated with TIBA had more laterals than those of the control, but they appeared later in the growing season. It would appear that TIBA was a strong growth inhibitor to both terminal and lateral bud primordia soon after treatments; however, after its effect was diluted by time, it induced breaking of the apical dominance by inhibiting the polar transport of auxin (2, 7, 45, 59, 77, and 104).

Figures 2, 3, and 4 are presented to illustrate the effects of the different regulators on the early stages of growth of cucumber plants grown in the fall of 1968 and 'Zucchini' squash plants grown in the spring of 1969. It appears that these effects are directly related to both flowering and fruit development.

In cucumber, concentrations of 100 ppm of MH or NAA slightly reduced the length of the main stem, but their effects on total plant growth were different. Plants treated with MH had more laterals and consequently more leaves formed on the plants than those treated with NAA. Plants treated with TIBA were much more dwarfed than those treated with MH or NAA, and their growth was retarded for a longer

period. Such effects were similar to those found in cantaloupe and watermelon.

In squash, since there are no laterals developed on the plant, one can use plant length as well as number of internodes as good indicators for plant growth. Treatment with GA stimulated plant growth, while the rest of the regulators had inhibitory effects in the following order: IAA, MH, NAA, and TIBA.

The results of the greenhouse experiments on both 'Yellow Straightneck' and 'Zucchini' squash are similar, and they lead to concrete conclusions about the interaction between natural and synthetic plant regulators used in these studies. Observations were:

1. Summer squash plants were not good indicators of sex expression because of the cluster of floral buds in the axil of each leaf instead of a single bud, as in 'Zucchini' squash.

2. There was a similarity in the growth response to the addition of GA and IAA between squash plants and dwarf varieties of corn, peas, and bean plants (15, 24, 59, and 84).

3. Treatments which affected sex expression also tended to cause changes in plant elongation. For example, GA caused an increase in shoot length, and the plant produced more male flowers, and IAA inhibited plant elongation and increased femaleness. Therefore, one can use plant length as a good indicator for the interaction between natural (GA and IAA) and synthetic (MH, NAA, and TIBA) regulators.

4. At the concentration of 100 ppm used in these

experiments, GA increased plant length by increasing both number and length of the internodes, IAA reduced both number and length of internodes, and treatment with a combination of both GA and IAA resulted in an intermediate effect.

Gibberellic acid exerts its effect on both cell expansion and cell division (15, 16, 36, 45, 95, and 111). Similar results were also reported by Brian and Hemming (24) on pea, Sachs (95) on Hyoscymus, and Phinney (84) on corn. In contrast to GA, IAA in higher concentrations inhibited both cell division and expansion which was demonstrated on different plants as early as 1937 by Went and Thimann (105). Observed interactions between GA and IAA were similar to those reported by other research workers (15, 16, 24, 36, 38, 45, 56, 77, 95, and 111).

Since the effects of GA plus IAA treatments were less than those of GA alone but higher than those of IAA alone, one may say that GA reversed the inhibition caused by IAA, or that IAA reduced the elongation caused by GA alone. Such effect might be a result of a balance in the ratio between GA and IAA within the plant.

Under the field condition (Fig. 4), a simultaneous spray with GA and IAA stimulated plant growth more than GA spray alone. This effect indicated a positive synergism, and was also reported before (24, 36, 45, 56, and 110).

Maleic hydrazide reduced both length and number of internodes in all experiments under both field and greenhouse conditions. Similar results have been reported on many plants (115 and 116). Rehm (91) reported that MH affects only the terminal growing parts of the

plant. However, in Avena coleoptile MH inhibits both cell elongation and cell division (115).

The findings of these studies indicate that GA interacted with MH to overcome its inhibitory effect (Tables 10, 13, 14, and 16); IAA could partially overcome the effect of MH if applied after MH treatment (Table 10); if both MH and IAA were applied together they caused more growth inhibition than either alone (Tables 13 and 16). These findings are in agreement with other investigators (Kato [56] and Riddell [24]), who found that GA could reverse the inhibitory effects of MH. In peas, Brian and Hemming (16) suggested that the inhibition of shoot growth caused by MH is due primarily to the activity of "GA-like" hormone. Results obtained by Olsen, Kulescha, and Pilet (24), however, indicated that MH does modify the endogenous auxin contents of plant tissues, and did not support the idea that MH is anti-auxin. Moreover there is some indication that MH may increase slightly the level of free auxin in pea roots (Audus [7]).

Naphthaleneacetic acid had more inhibitory effects on plant growth than IAA (Tables 11 and 13). Both the number and the length of internodes were reduced by NAA. Treatments with IAA did not overcome the inhibition caused by NAA; however GA completely reversed the inhibition caused by NAA on both number and length of internodes. This is in complete accordance with the findings reported by Laibach and Kribben (44), Kato (56), and Galun (35) on cucurbitaceous crops, and with many other research workers on ornamental and fruit crops.

Triiodobenzoic acid severely inhibited plant growth and reduced both number and length of internodes. Treatments with IAA

were more effective in overcoming TIBA inhibition on the number of internodes than plant length (Tables 11 and 13). These findings indicate that TIBA might exert its inhibition by blocking the action of both endogenous IAA and GA on plant growth.

Galston 1947, reported that TIBA caused morphological changes in soybeans such as shortening of the internodes, loss of apical dominance and epinasty of young leaves. His observation, that TIBA inhibited the action of auxin in the Avena Test, suggested that TIBA might act as anti-auxin. However, there was no evidence to supply convincing proof of this idea. Audus and Shipton (7) suggested that it was possible that the inhibition of auxin action in this test was due to a general growth inhibition not specifically connected with auxin. It is well accepted that TIBA has a high specific capacity for modifying the polar transport of auxin in plant tissues (45, 59, 77, and 104).

Sex Expression

The idea of floral bud bisexuality is not new. Schaffner and Yampolsky (44) repeatedly pointed out that there cannot be a total loss of genetical capacity for the expression of the sex not normally manifest in an individual, for it is usually possible through environmental agencies to evoke functionally perfect male organs in female plants, and vice versa.

This idea, along with the findings of Ito and Saito (48, 49 and 50), and Atsmon and Galun (5), supports the conclusion that floral buds in the cucurbitaceous plants are bisexual in nature. This means that during development from primordia to anthesis the cucurbitaceous

floral bud passes through various stages. All floral buds pass during their ontogeny through a bisexual stage. Unisexuality is attained by supression of the pistillate structure in the male, and the staminate structure in the female. A hermaphrodite flower is produced by the development of both sex organs.

Based on his studies on hemp as well as on a review of literature, Heslop-Harrison (44) suggested that sex expression is regulated by the level of a growth substance (florigen), and that there were two different thresholds. The lower threshold represented the transition from the vegetative state to the staminate phase, and the higher threshold represented the shifting from the staminate to the pistillate sex expression. But "florigen" itself was,and still is, in the realm of hypothesis.

Arguing from their findings with cucumber, Laibach and Kribben (44) have suggested that the sexuality of a flower is dependant upon the concentration of native auxin levels available to the leaf axil during the period of flower formation. This viewpoint is supported by the findings of many others (5, 6, 35, 37, 44, 45, 49, 50, 59, and 77).

In his review article (92), Resende, in 1967, described the degree of flower development (floral gradient from vegetative to floral flower) as it may be controlled by the ratio of growth promoters to growth inhibitors. The higher this ratio, the more vegetative the flower will be, and the very high values will lead to a total regression to the vegetative state. He also suggested a hypothesis which may be summarized as follows: Sex expression in angiosperms is

controlled by a group of structural genes, subgroups of which are responsible for the calyx, the gynoecium, the corolla, and the androecium. The activation of these genes is governed by the establishment of a specific ratio of growth promoters to growth inhibitors. The balance of this ratio of growth regulators (morphoregulators) is postulated to be controlled by a system of additive genes, which regulate expression and repression of the structural genes.

If, therefore, the former system (structural genes) is a fixed one, all the variation covering genotypically determined monoecia, dioecia, gynodioecia, gynomonoecia, and andromonoecia (Westergaard, [106]) might be explained taking into account simply the variation within the additive genes regulating the balance of growth promoters to growth inhibitors. However, this system does not cast any light on the nature of these growth promoters and inhibitors.

It might be helpful here to quote from the review article on the physiology of flower and fruit development by Nitsch (77), "As a whole, there seems to be a correlation between the development of certain flower parts. Thus, factors which favor the development of ovary also favor that of sepals, those favoring stamen development favor also the development of corolla."

The results of the current studies on sex expression are in a complete agreement with the findings of other investigators (5, 6, 17, 36, 38, 45, 56, 59, 77, 85, 86, 103, 111, and 112) in that GA promoted maleness and supressed femaleness of the plants. In the field experiments (Tables 3, 5, and 7), GA treatments enhanced the appearance and increased the number of staminate flowers. Gibberellic acid also

delayed the appearance of either pistillate (in cucumber and squash) or hermaphrodite (in cantaloupe) flowers. Inodoleacetic acid treatments had completely opposite effects to those of GA. Inodoleacetic acid enhanced pistillate flower production and reduced the staminate phase. However, in both cucumber and squash (Tables 3 and 5) treatments with a mixture of IAA and GA delayed flowering in general by decreasing the total number of flowers developed during the first week of flowering, but in the following week sex expression was shifted toward femaleness.

Experimental results in the greenhouse were similar to those of the field, but they put more emphasis on the interaction between the different regulators affecting plant growth and sex expression. The availability of a 'Zucchini' hybrid minimized the possibility of any genetic variability between plants which might affect plant growth and sex expression.

From the results of the first experiment (Table 10), it is safe to conclude that GA treatments alone stimulated vegetative extension and shifted sex expression toward maleness. Naphthaleneacetic acid on the other hand inhibited elongation. However, one should notice two other effects: first, when seeds were soaked in GA, a consequent spray with IAA did not reduce the effect of GA on elongation, but it did reverse the effect on sex expression; second, when seeds were soaked in IAA, a subsequent spray with GA produced its stimulating effect on elongation but did not affect sex expression. This latter effect might be explained on the basis that seed soaking in GA did not exert its effect on sex expression immediately, and a

subsequent IAA spray might have modified the ratio IAA/GA before the sex expression of most floral primordia is established. On the other hand, seed soaking in IAA might have an immediate and prolonged effect on the sex expression of floral primordia, or GA sprays did not modify the ratio of endogenous IAA/GA enough to supress female sex expression.

In the 'Zucchini' squash experiments (Tables 12, 13, and 14), GA seed soaking or plant spray treatments shifted sex expression toward maleness by changing the sex of the floral buds on the upper nodes (the nodes from 10 to 13 carried female flowers in the control plants), and seed soaking plus plant spray with GA produced completely male plants. Indoleacetic acid treatments increased female tendency by modifying the sex of the floral buds located on the nodes from 6 to 11 of the treated plants. However, in cases where both GA and IAA were applied on the same plants, sex expression was almost like that of the control plants.

The above results lead to the conclusion that sex expression in the cucurbitaceous plants might be controlled through the levels of endogenous auxin and gibberellin in the plant. Whether or not these levels have a direct or indirect effect on sex expression, it is clear that high levels of GA favored vegetative extension, formation of staminate flowers, and prolonged the staminate phase. High levels of auxin, on the other hand, inhibited vegetative extension, shortened the staminate phase, and increased and accelerated morphologically and chronologically the formation of pistillate flowers.

At present there seems to be considerable evidence which supports

that conclusion. The fact that synthetic auxins increase the ratio of pistillate to staminate flowers in cucurbits has been reported by many researchers (12, 13, 22, 35, 46, 49, 59, 77, 110, and 112). This may be caused by either an increase in the relative number of female flowers, a decrease in male ones, or both. Actually synthetic auxins reduce the number of male flowers to such an extent that they have been suggested as a means of inducing male sterility in plants (44, 45, 46, 91, and 110).

Galun (35) was not able to detect any significant differences in the auxin contents of normal, monoecious and purely gynoecious plants of cucumber. However, he was able to show in a later in vitro experiment that very young flower primordia of cucumber excised from nodes which would have formed male flowers could be caused to develop into female flower buds if 0.1 mg/l of IAA was added to the nutrient medium.

It is clear also from the work done with GA (17, 37, 38, 43, 83, and 86) that this hormone does not only alter sex ratio in monoecious cucurbits, but it also causes the production of staminate flowers on completely gynoecious lines of cucumber.

According to the foregoing results and evidence, the following hypothesis appears to be warranted:

1. The sex of flower primordia in monoecious cucurbits passes through a bisexual stage and is expressed as male or female due to the physiological and environmental factors.

2. Sex expression in cucurbits is controlled by the ratio of auxins to gibberellins in the plant especially in

the tissues in the subapical region of differentiation and within floral primordia before the bisexual stage. The higher this ratio the greater tendency for female sex expression, and the lower the ratio the more male the tendency.

3. Endogenous levels of auxin and gibberellins could control sex expression directly or indirectly--directly through the effect of GA and IAA per se on gene repression and derepression, and indirectly through the effect of these two hormones and their interaction with other plant regulators on plant growth, development, and metabolism. In any case, higher levels of GA favor vegetative extension and male sex expression; however, high levels of IAA tend to inhibit vegetative growth and induce female sex expression.

Such a hypothesis is in agreement with the assumption of Resende (92) on the effect of growth promoters and growth inhibitors on genes and sex expression. It is also supported by the ideas and the findings of other investigators (5, 6, 12, 17, 37, 41, 43, 45, 56, 59, 76, 77, 83, 85, 110, 111, and 112).

It does not contradict the assumption of the flowering hormone (florigen) as suggested by Chailakhyan (21). If indeed florigen is in existence and it is either composed of two hormones, gibberellin and anthesin, then we can say that IAA might play its role by modifying the proportion of these two hormones and their action on both flowering and sex expression. Or it may be more reasonable to assume that such a hormonal complex (florigen) is merely a polymer of different plant hormones and the proportional ratio of these hormones is the determining factor in regulating plant growth and development.

Following the same line of reasoning, one could conclude the following: First: the effect of NAA on sex expression might be a direct effect as a synthetic auxin which favors female sex expression, or an indirect effect through the modification of endogenous levels of IAA and GA. Second: both TIBA and MH had similar effects on vegetative growth and sex expression, and their action might be attributed to one or more of the following mechanisms:

1. They inhibit and retard vegetative growth and extension: changes which might result in a build up in IAA levels in the plant tissues, especially in the stem.

2. They have a direct effect on the inhibition of the polar transport of IAA in the stem causing a build up of IAA levels in the apex and in the area of primordial differentiation.

3. They have antagonistic effects and reactions toward GA which block or dilute its action on both vegetative growth and sex expression.

Fruit Growth and Development

The physiological and chronological determinations of marketable yields of cucumber and summer squash are different from those of cantaloupe and watermelon. Cucumber and squash fruits are harvested at about 6 to 12 days from the time of fruit set while they are physiologically immature. However, cantaloupe and watermelon fruits are harvested in the physiologically mature stage after about 35 to 50 days from the time of fruit set. Both cucumber and squash plants develop and set numerous fruits which are multi-harvested during a

4 to 8 week harvesting period. In other words, fruits which are set and developed early in the season, if harvested at the proper time, do not compete with those which are set and developed later in the season. Regardless of the number of pistillate flowers developed and fruit set on cantaloupe and watermelon plants, each plant is able to support and develop only 1 to 3 marketable fruits within the normal growing season.

In both squash and cucumber the number of marketable fruit is dependent on the number of pistillate flowers developed and set per plant, and earliness of the crop is a function of both fruit setting time and the rate of fruit growth and development. On the other hand, earliness and total yield of cantaloupe and watermelon do not depend on the number of pistillate flowers as much as they are dependent on the time of fruit setting and the rate of fruit growth and development. The earlier the fruit sets and the faster it develops, the earlier it can be harvested and the higher will be the early yield.

Results of the three seasons experiments with cucumber (Tables 1, 4, and 5) indicate that all treatments of MH in spring 1967, treatment with 100 ppm MH in spring 1968, and both 100 ppm and 200 ppm treatments of MH in fall 1968 increased the number of fruits harvested early. However, treatments with 150 and 200 ppm MH in spring 1968 decreased early yield. These different effects of concentrations might be due to different plant responses in the spring than that in the fall. All of MH treatments in all experiments increased the number of pistillate flowers developed early in the first two weeks, but there were different effects on the inhibition of vegetative

growth. Double spray treatments in 1967 and higher concentrations in 1968 had more inhibitory and lasting effects than those of single sprays and lower concentration (Tables 1 and 4 and Figures 2 and 5). These results also indicate that early yields were in proportion to vegetative growth and number of pistillate flowers. On the basis of these results, we can say that all treatments with MH enhanced early formation of pistillate flowers and inhibited vegetative growth. Those treatments which slightly inhibited growth reduced the competition between vegetative and fruit growth, and, as a result, increased early yield. Other treatments caused more inhibition to vegetative development which reduced the ability to support the developing fruits and reduced early yield.

In the same way, we can explain the results of both NAA and TIBA treatments. Naphthaleneacetic acid treatments had more and TIBA the most inhibitive and lasting effect on vegetative and reproductive growth and development. However, effects of GA, IAA and a mixture of GA and IAA treatments on yield were directly related to their effects on both vegetative growth and sex expression.

Results with squash show that treatments with MH and NAA at the two-leaf stage in spring 1967 and MH 100 ppm were the only treatments which increased early yield, while the rest of the treatments had no effect, decreased yields, or resulted in no early yield at all (Tables 2 and 6). These results are different from those of cucumber because the number of flower buds and the number of leaves in squash are merely dependent on the number of developed internodes on the main stem. Those treatments which slightly decreased vegetative

growth also accelerated the development of early fruits and increased early yield; however, the rest of the treatments inhibited growth by decreasing both length and number of internodes and number and size of leaves which decreased plant metabolites and delayed fruit growth and development.

This conclusion is also supported by results of treatments with higher concentrations of NAA and TIBA which resulted in dwarf plants that produced smaller fruits with either abnormal shape or size.

Early and total yield of watermelon and cantaloupe is directly related to the state of vegetative growth. Treatments which enhance early development of pistillate flowers might also increase early yield, if the competition between vegetative and fruit growth in the earlier stages of fruit development was decreased. Such was the case with the treatments of 100 and 150 ppm MH in the spring 1968 and MH and IAA in the fall 1968 in cantaloupe (Tables 8 and 9), and all treatments with MH and NAA at the two-leaf stage in 1967 and 100 and 150 ppm MH and 100 ppm NAA in 1968 in watermelon (Tables 3 and 7). Treatments which decreased the vegetative growth severely delayed both fruit setting and fruit growth and development, decreased the number of fruit in early harvest, or delayed yield to the later harvests. Such are clearly illustrated in the results of treatments with TIBA and high concentration of NAA (Figures 7, 8, 9, and 10).

Total yield is a direct result of the number and size of fruits which are marketable at harvest time. It depends on the number of fruit set early in the season and their rate of development during the growing season. These two characteristics are directly

related to the number of pistillate flowers, percent fruit setting, and the competition between vegetative and reproductive growth. Total yield was increased in cantaloupe by treatment with lower concentration of MH, TIBA and IAA, and by MH and NAA in watermelon. These results might be attributed to the effect of these treatments on increasing the number of early pistillate flowers, the ratio of fruit setting, and the acceleration of fruit growth.

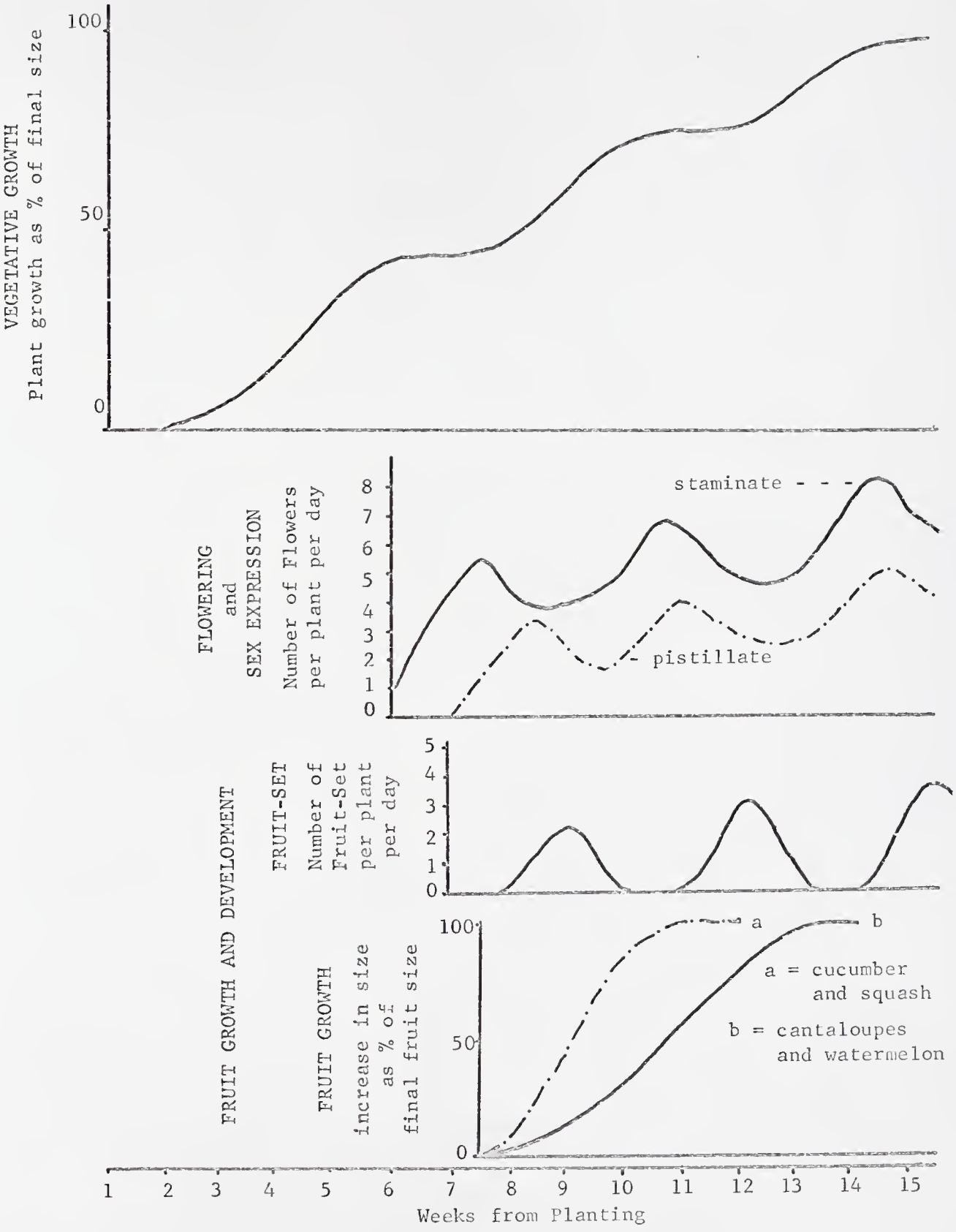

Figure 1. Schematic Review of the Overall Plant Growth and Development of the Cucurbitaceous Plants in General.

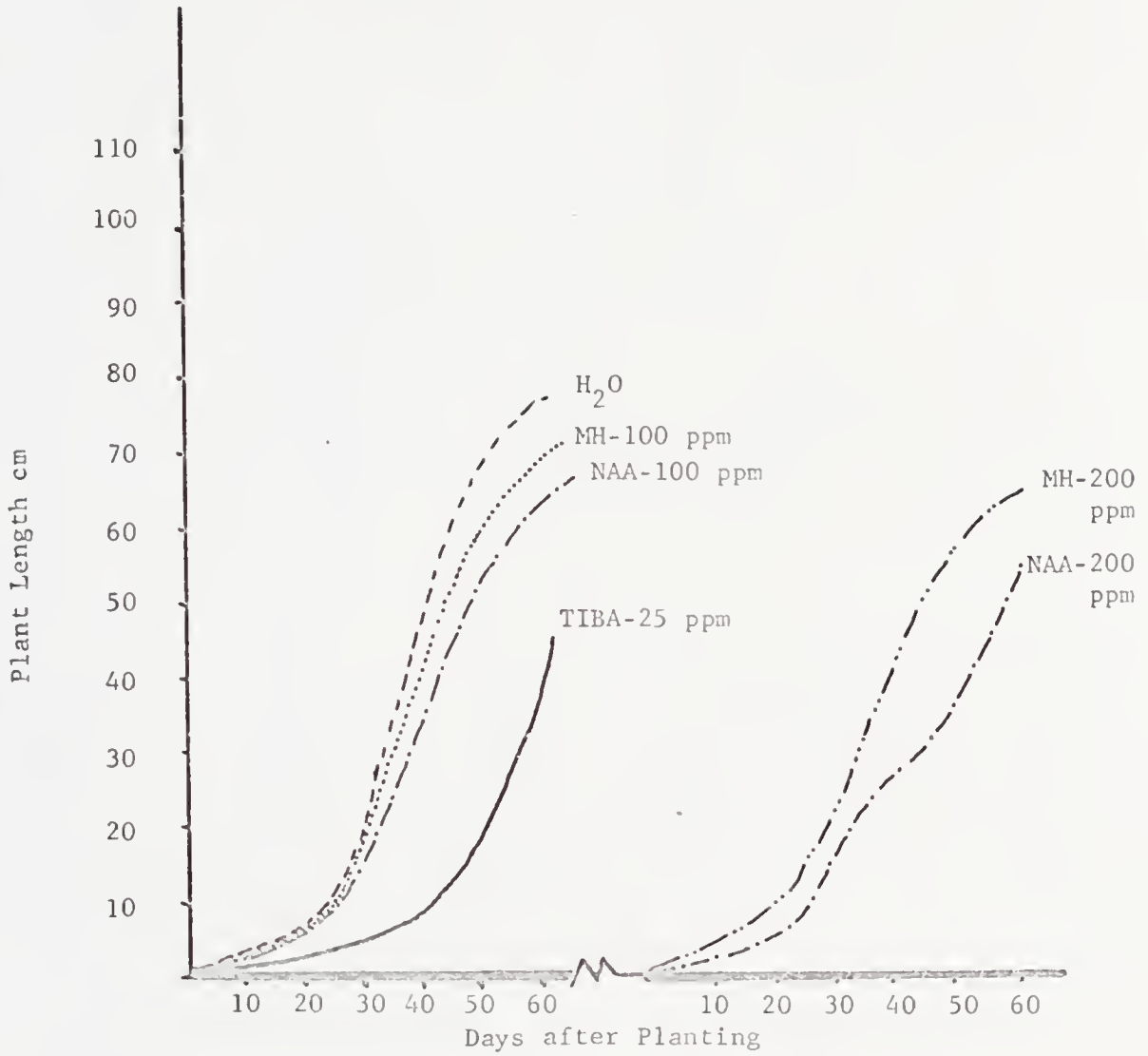

Figure 2. Stem Elongation of Field Grown Cucumber (Fall, 1968) in Response to Treatments with Different Chemical Regulators.

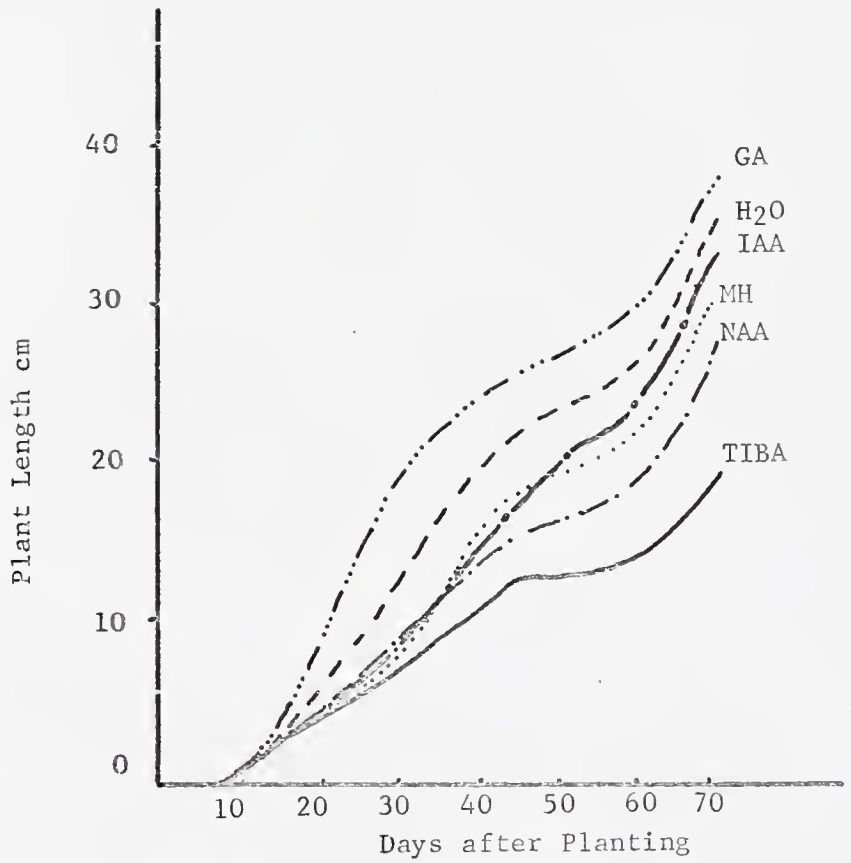

Figure 3. Effects of Different Chemical Regulators on Stem Elongation of Field Grown Zucchini Squash (Spring, 1969).

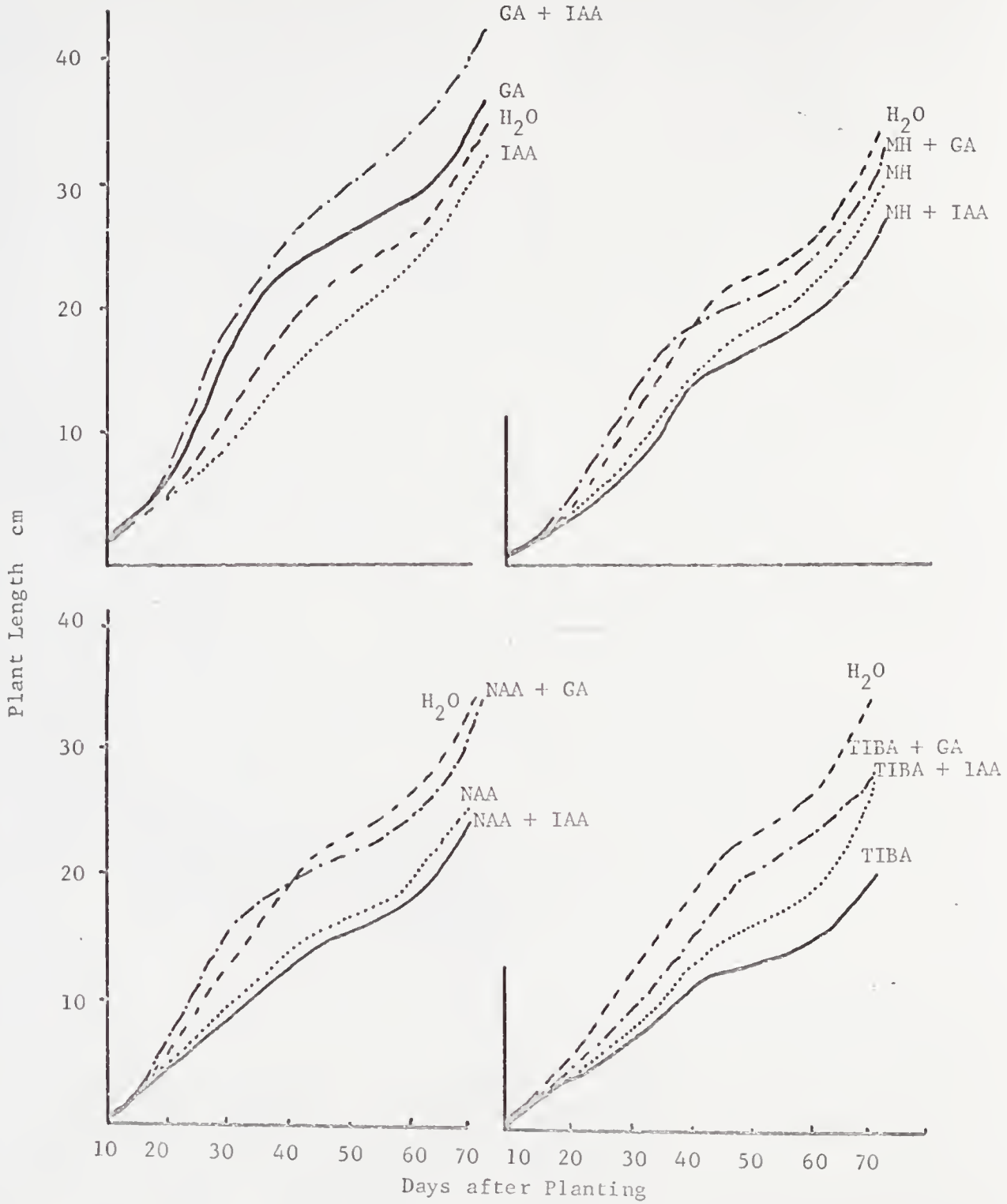

Figure 4. Effects of the Different Chemical Regulators and Their Interactions on Stem Elongation of Field Grown Zucchini Squash (Spring, 1969).

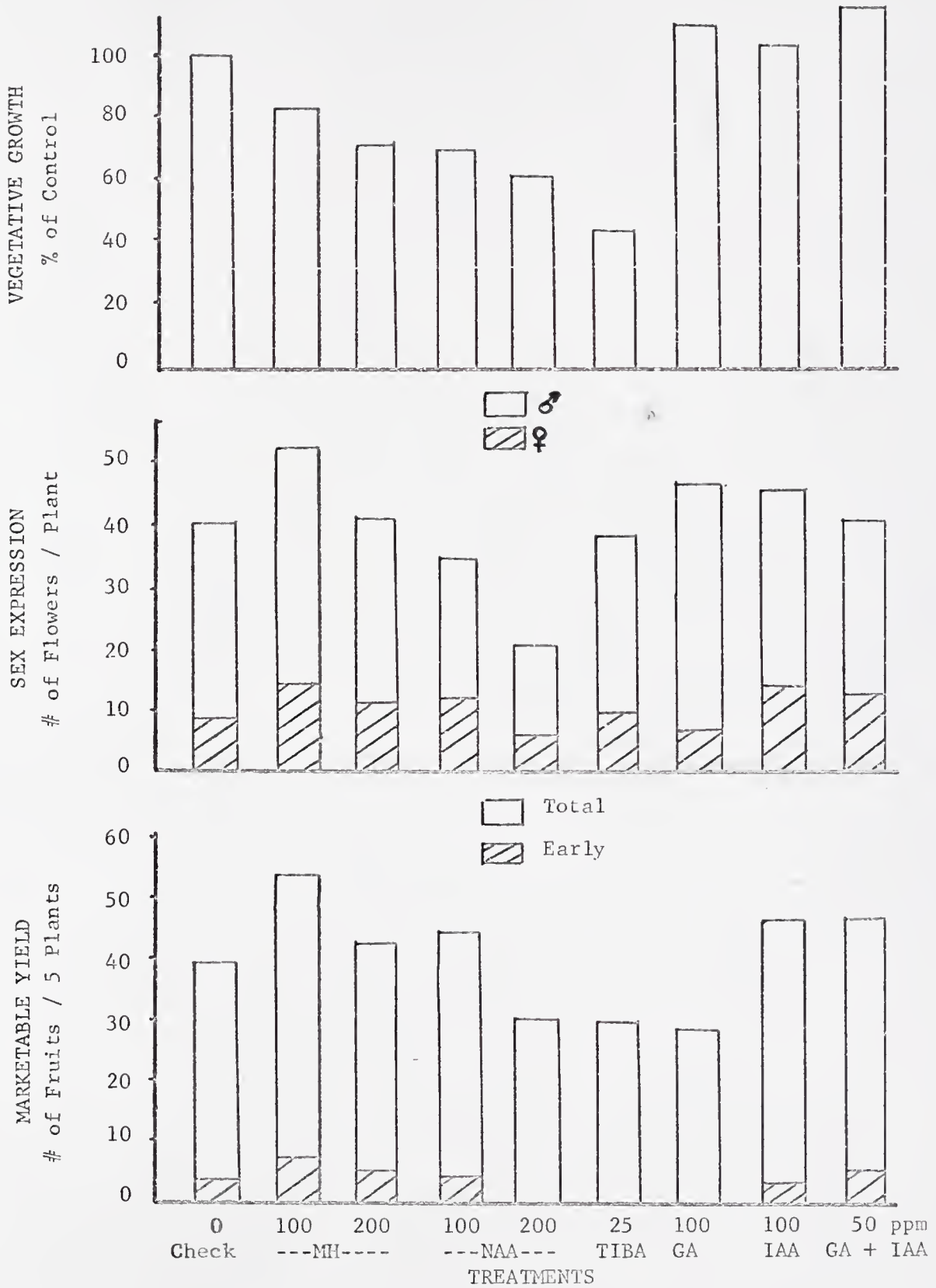

Figure 5. Influence of Regulators on Vegetative Growth, Sex Expression, and Marketable Yield of Cucumber (Fall, 1968).

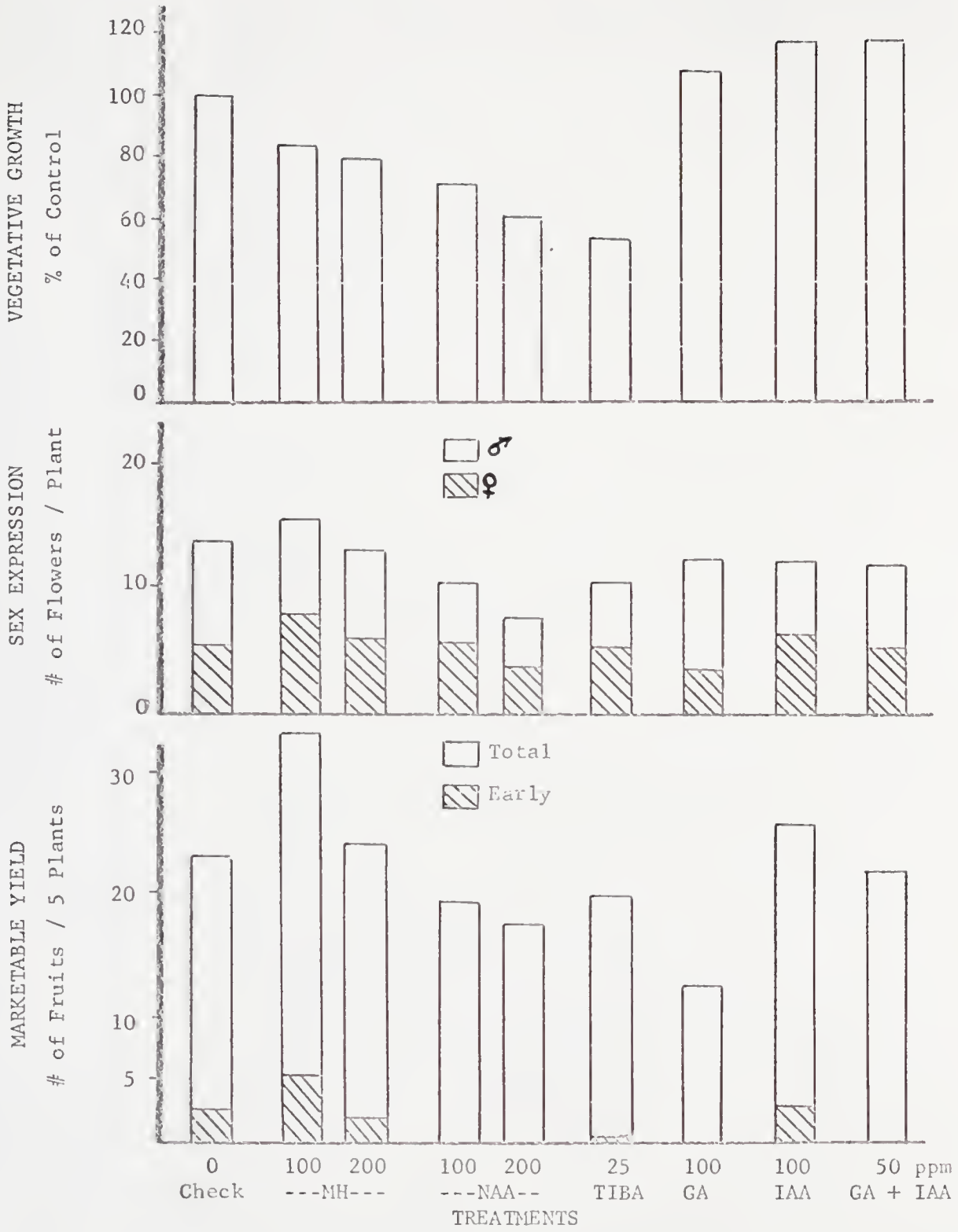

Figure 6. Effects of Regulators on Vegetative Growth, Sex Expression, and Marketable Yield of Squash (Fall, 1968).

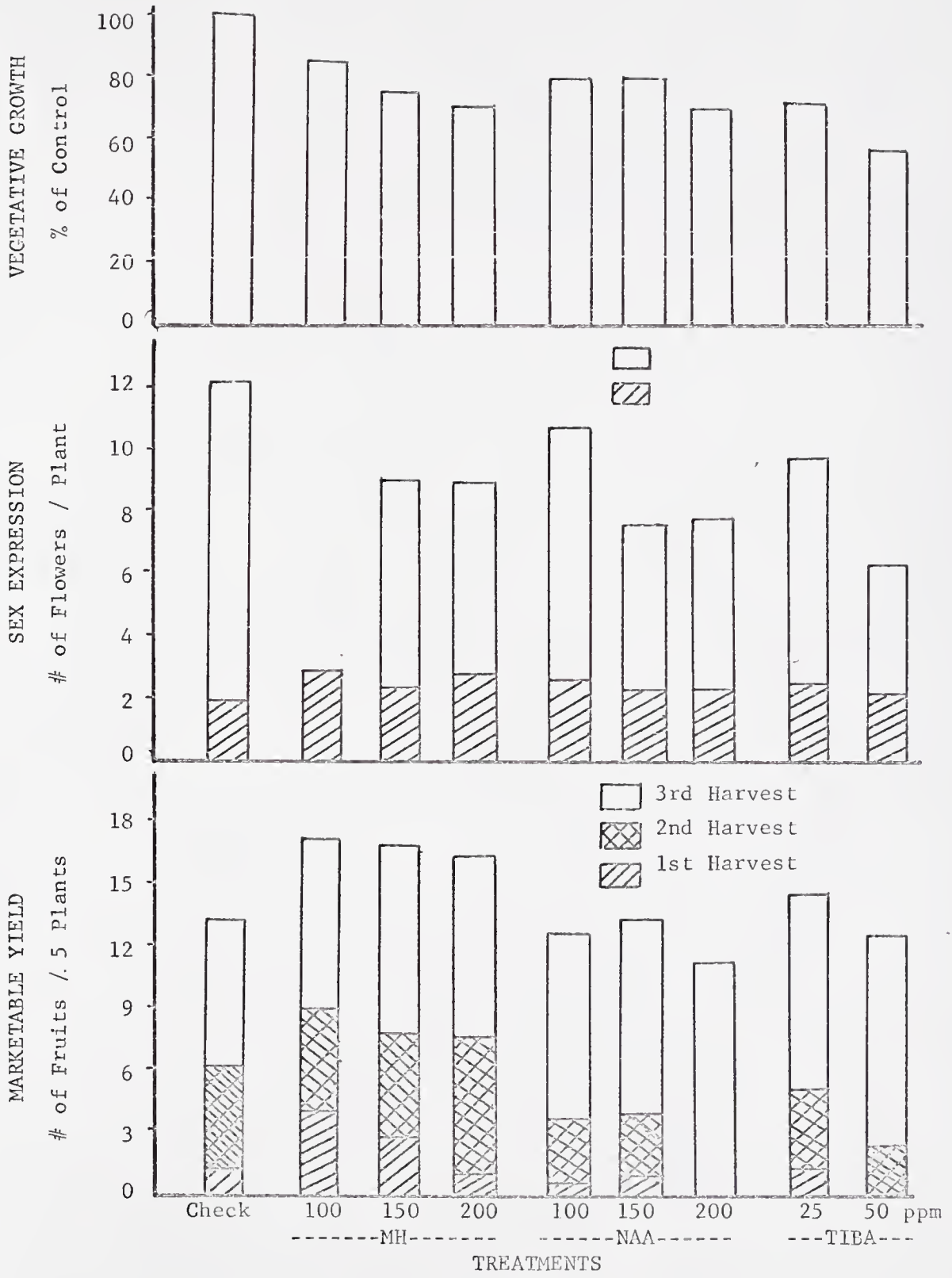

Figure 7. Regulators' Effects on Vegetative Growth, Sex Expression, and Marketable Yield of Cantaloupe (Spring, 1968).

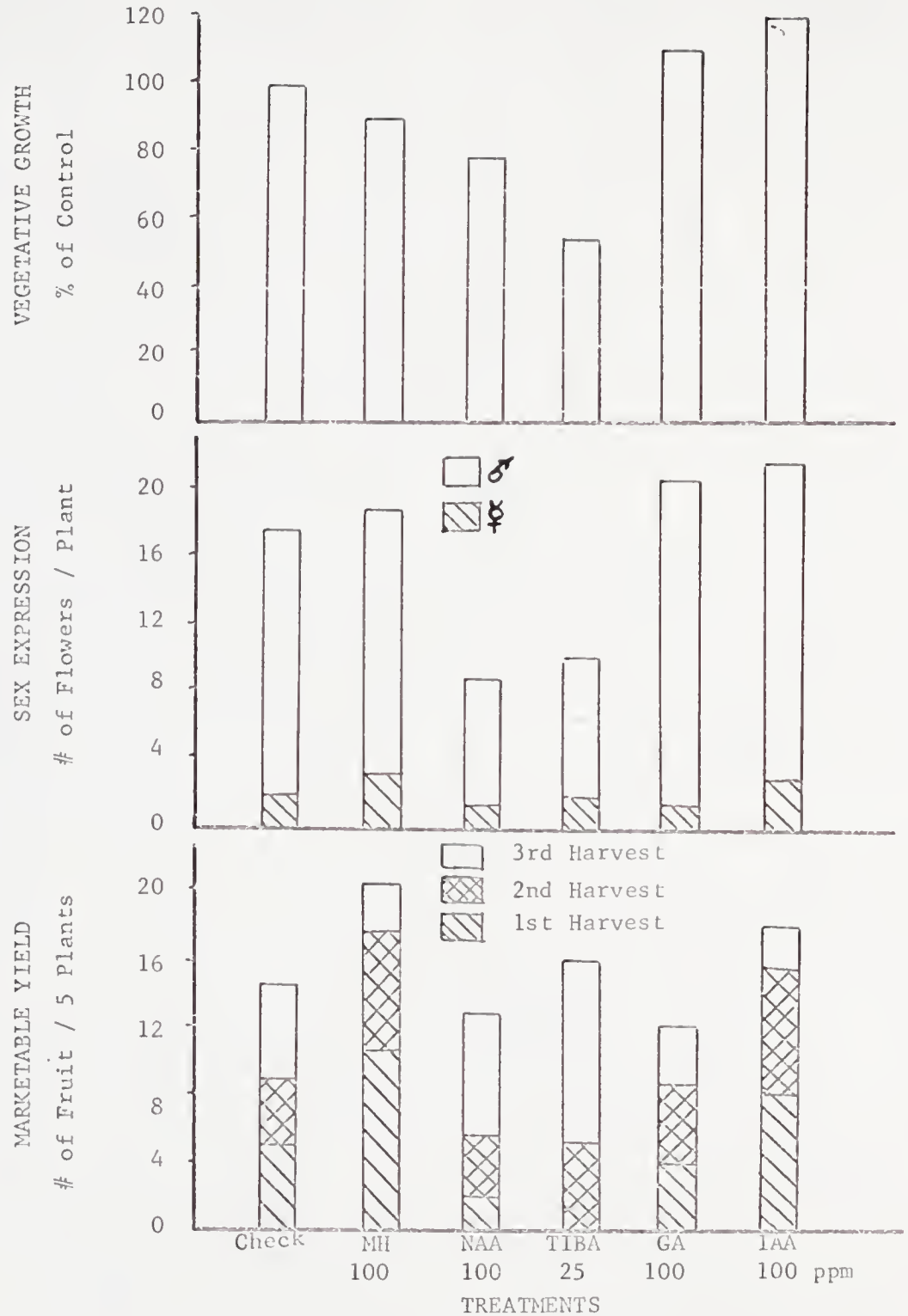

Figure 8. The Influence of Regulators on Vegetative Growth, Sex Expression, and Marketable Yield of Cantaloupe (Fall, 1968).

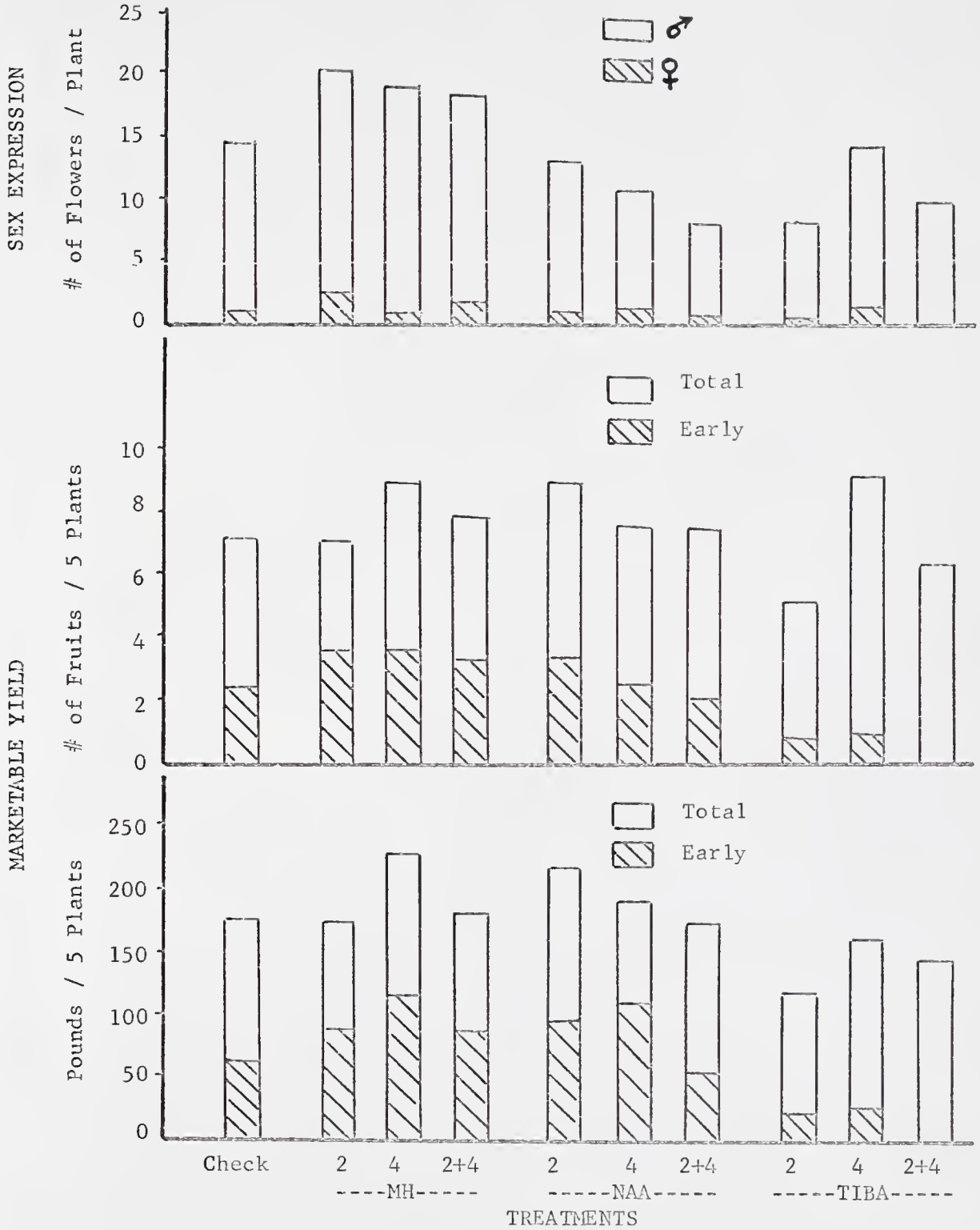

Figure 9. Effects of Regulators on Sex Expression and Marketable Yield of Watermelon (Spring, 1967).

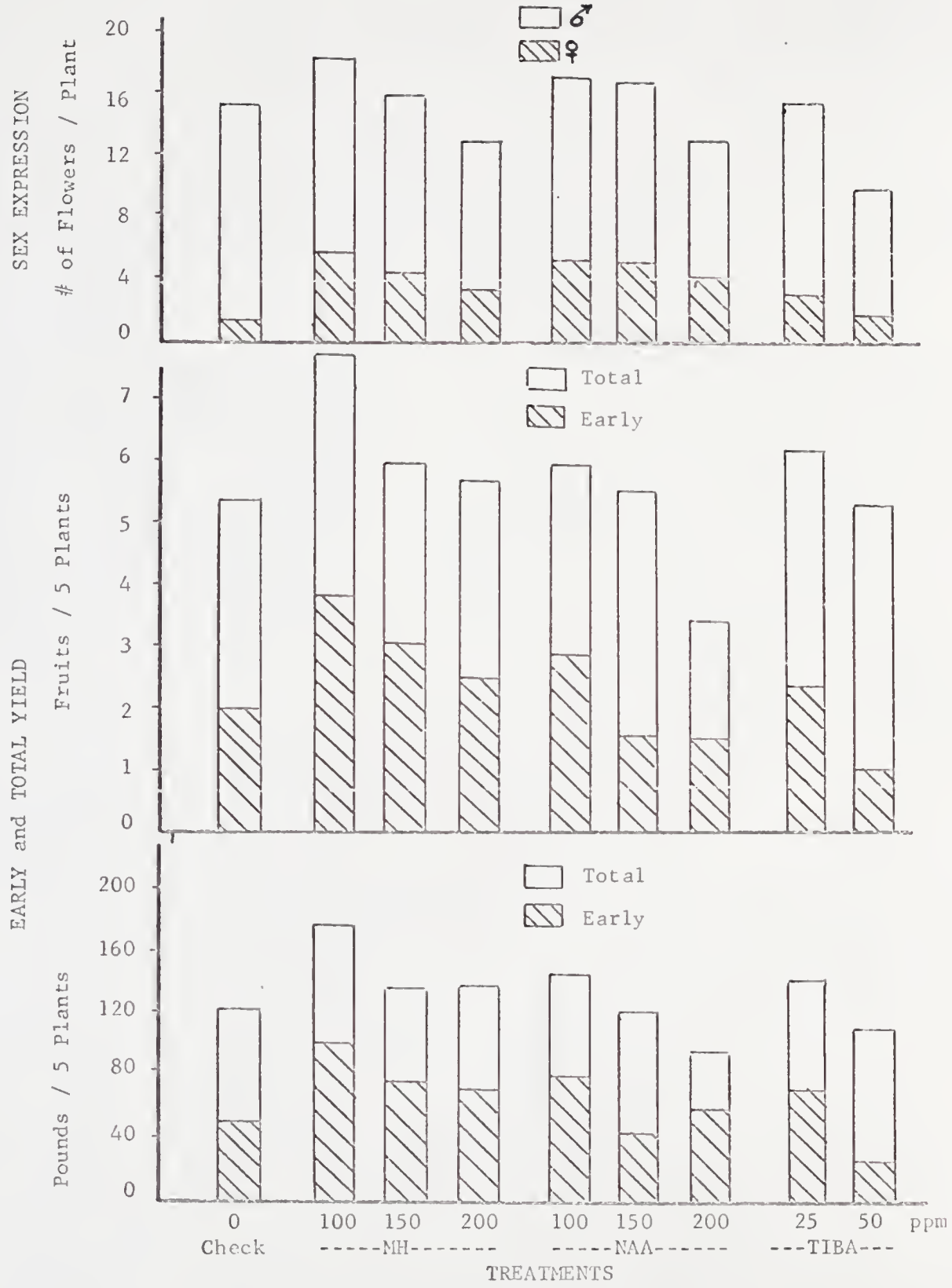

Figure 10. Regulators' Effects on Sex Expression and Marketable Yield of Watermelon (Spring, 1968).

SUMMARY AND CONCLUSION

Studies were conducted using some growth regulating chemicals to modify the flowering and sex expression of cucurbits and to achieve one or more of the following objectives: to increase earliness of the crop, to increase total yield, or to concentrate flowering and fruit set into a shorter period. Crops used in these studies were cucumber, summer squash, cantaloupe, and watermelon. Growth regulators selected were MH, NAA, TIBA, GA, and IAA.

The experimental program was divided into a field phase to study the effect of spraying the plants with regulators on the production of these crops, and a greenhouse phase to determine the mechanism by which these regulators produced their effects.

All the treatments modified plant growth, sex expression, and fruiting under both greenhouse and field conditions. Treatments with MH, NAA, TIBA, and IAA reduced vegetative growth, suppressed staminates, and enhanced pistillate flower development. Multiple applications and higher concentrations of these chemicals inhibited plant growth more than a single application or lower concentrations. Treatments with GA increased vegetative growth, enhanced staminate, and suppressed pistillate flower production.

Early and total yields were increased by applications of 100 ppm of MH, NAA, or IAA in a single spray at the four-leaf stage in all crops. Treatments with TIBA at 25, 50, or 100 ppm, MH at 200

ppm, and NAA at 200 ppm showed promising results for harvest concentrations.

Experimental results, observations, and a review of pertinent literature appear to support the following hypothesis:

1. The sex of flower primordia in monoccious cucurbits passes through a bisexual stage and is expressed as male or female due to physiological and environmental factors.

2. Sex expression in cucurbits is controlled by the ratio of auxin to gibberellins within flower primordial tissues before the bisexual stage. The higher this ratio the greater the tendency for femaleness and the lower the ratio the more male the tendency.

3. Endogenous levels of auxin or gibberellins could control sex expression directly through their effects on gene expression and repression, or indirectly through their effects on other plant hormones, plant metabolism, or plant development.

It is reasonable to conclude the following: First: the effect of NAA on sex expression might be a direct effect as a synthetic auxin which favors female sex expression, or an indirect effect through the modification of endogenous levels of IAA and GA. Second: TIBA and MH had similar effects on vegetative growth and sex expression, and their action might be attributed to one or more of the following mechanisms:

1. They inhibit and retard vegetative growth and extension; changes which might result in an increase of IAA levels in the plant tissues especially in the stem.

2. They have a direct effect on the inhibition of the polar transport of IAA in the stem, causing a build up of IAA levels in the apex and in the area of primordial differentiation.

3. They have antagonistic effects and reactions toward GA which block or dilute its action on both vegetative growth and sex.

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BIOGRAPHICAL SKETCH

The author, Mohamed Abdel-Rahman, was born on July 3, 1941, in Cairo, Egypt. In June, 1958, he was graduated from the Kubbah High School in Cairo. He attended the College of Agriculture, University of Ain-Shams, in Cairo, from September, 1958 to June, 1962. During that period he obtained the highest grade point average in his class of 600 students, and he received the state's awards and scholarships for the most outstanding student. In June, 1962, he graduated with grade A and honor degree and received the national award for the best graduate in Agriculture in 1962 from President Gamal Abdel-Nasser.

From September, 1962 to October, 1965, he served as instructor in the Department of Botany, College of Agriculture, University of Ain-Shams, Cairo, and while teaching he completed the requirements for the Master of Science degree in Plant Pathology in 1965 at the same department.

He entered the University of Florida in January, 1966, and completed his work toward the degree of Doctor of Philosophy in August, 1970, from the Department of Vegetable Crops.

He is a member of the American Society for Horticultural Science, Florida State Horticultural Society, and the American Society of Plant Physiologists.

He is married to the former Miss Janine M. Neerdaels and they have a daughter, Magda.

This dissertation was prepared under the direction of the chairman of the candidate's supervisory committee and has been approved by all members of that committee. It was submitted to the Dean of the College of Agriculture and to the Graduate Council, and was approved as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

August, 1970.

Dean, College of Agriculture

Dean, Graduate School

Supervisory Committee:

Chairman